FIRST STARS DETECTED
WHAT THE NEW DISCOVERY MEANS

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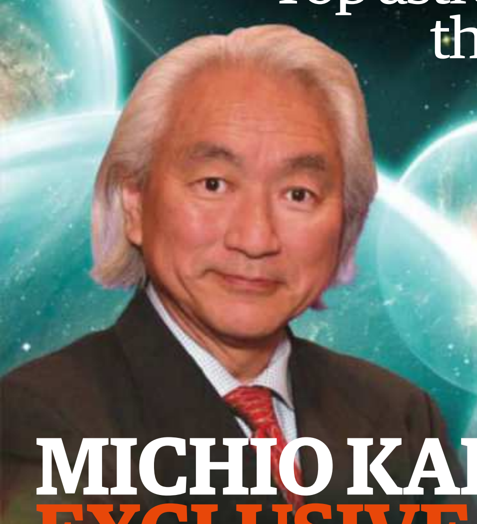
TRUMP'S NEW PLANS FOR NASA
THE VERDICT

All About Space

MODEL ROCKET OFFER INSIDE

OUR *WEIRD* SOLAR SYSTEM
Our planets have something to tell us

DO BLACK HOLES LEAK INTO PARALLEL UNIVERSES?
Top astrophysicists reveal how they've solved the greatest paradox ever known



TIME IS IT AN ILLUSION?

MICHIO KAKU EXCLUSIVE
- How warp drives are possible
- The search for alien life
- Your guide to string theory

FUTURE
ISSUE 076

WHAT'S NEXT FOR HUBBLE

+ MARS ROVER BREAKS RECORD • GRAND NIGHT SKY TOUR • VIXEN VMC 110L REVIEW

Hubble has been watching the universe for 28 years

@ Adrian Mann

Welcome

Parallel universes. They're the universes that could exist quite comfortably next to ours, creating a so-called multiverse. What's more, they could solve a pretty complex problem with black holes: where does the information that falls into them go? Is it destroyed, violating quantum mechanics, or is it enveloped by a blazing firewall, completely defying Einstein's famous theory of general relativity? It's a puzzle. That's where parallel universes come in - according to recent research, it could be that black holes are leaking all of their information from our cosmos into another. This issue, we chat to the astrophysicists who are untangling the conundrum. Turn to page 16 as they reveal how they've solved the mystery of black holes - the greatest paradox ever known.

Elsewhere, we find out why our Solar System is incredibly odd, reveal where time comes from and give you the tools in spotting those fake space photos you find on the Internet. Physicist Michio Kaku, known for his books including *The Future of Humanity*, dropped by to provide his ultimate guide to the complex universe - he's made string theory digestible, reveals if the interstellar warp drive is actually going to be possible and has weighed in on the launch of SpaceX's Falcon Heavy rocket. There's plenty to get stuck into this month - enjoy the issue!

Gemma Lavender
Editor

"We look forward to overlapping operations with the JWST and the resulting science opportunities" **Patrick Crouse, Page 39**

Our contributors include...

Colin Stuart
Astronomer & author
Black holes could be leaking information! But are they oozing it into another universe? Colin spoke to the experts with the details over on page 16.

Michio Kaku
Physicist & futurist
The physicist uncovers whether we're living in a hologram, what he thinks of Elon Musk's decision to launch a Tesla into space and gives you the ultimate guide to string theory.

Lee Cavendish
Staff Writer & astronomer
What's next for the Hubble Space Telescope? Lee chats to the NASA scientists behind the mission to uncover the details.

Luis Villazon
Space science writer
Luis speaks to the planetary scientists who have revealed why our solar neighbourhood is a really weird place as far as planetary systems go. Turn to page 26.

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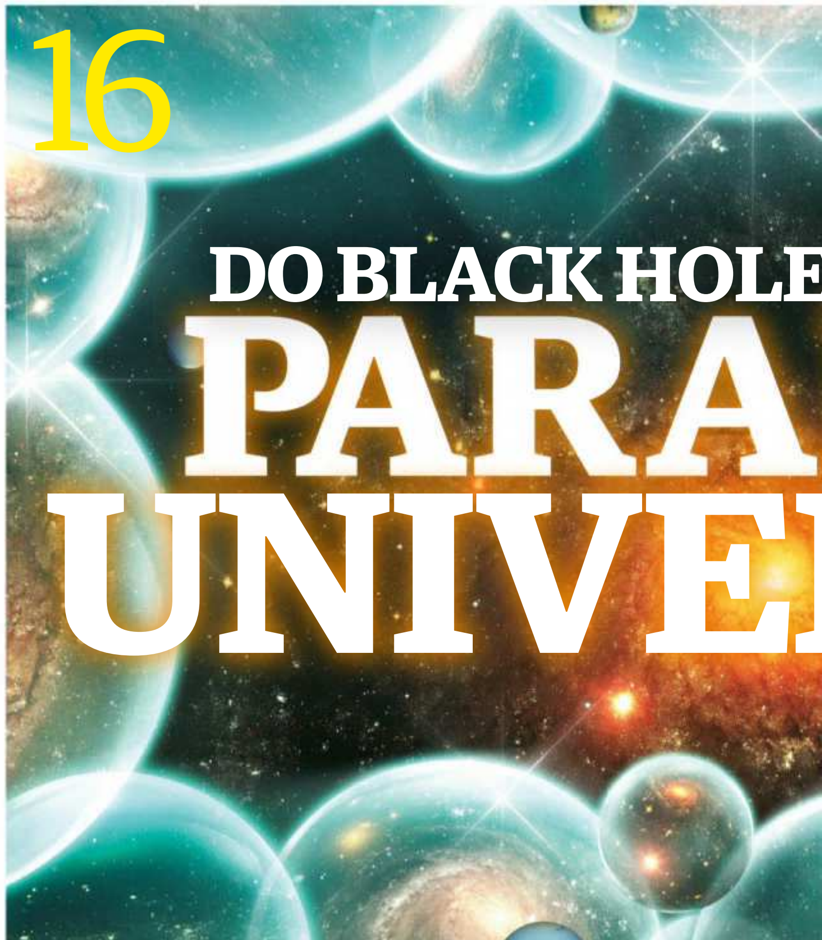
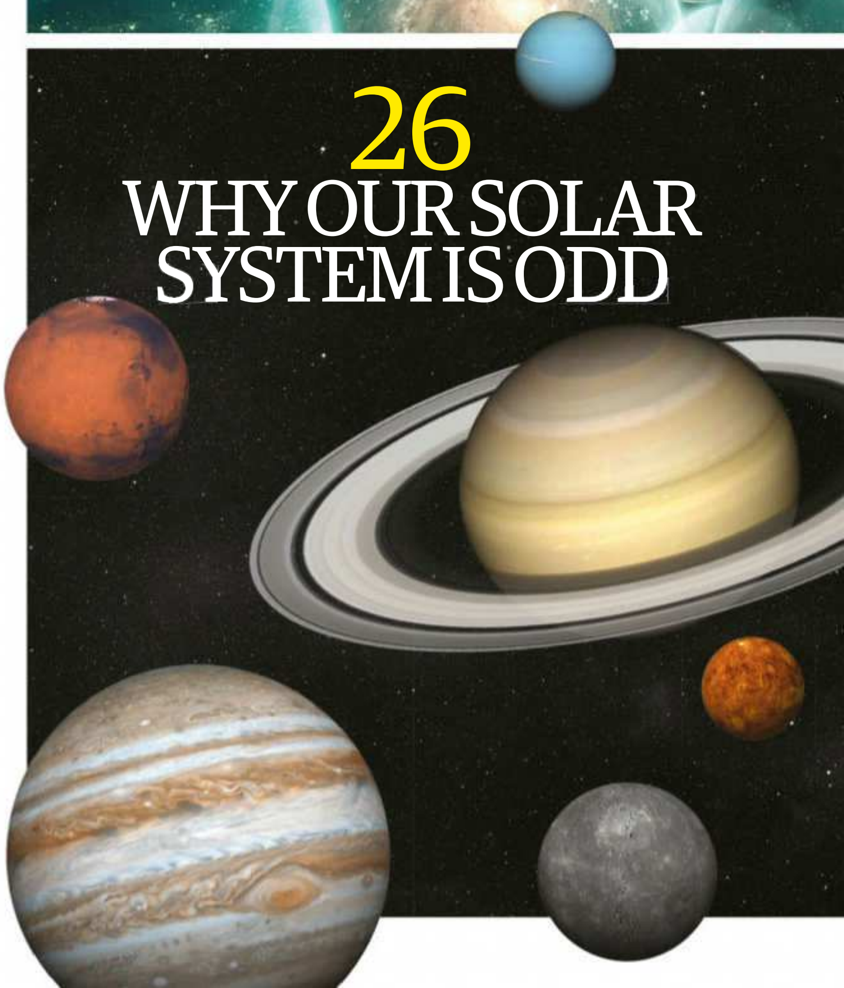
LAUNCH PAD
YOUR FIRST CONTACT WITH THE UNIVERSE

FEATURES





"Time is just the label we put on those different versions that happen one after another"

48 Professor Sean Carroll
California Institute of Technology

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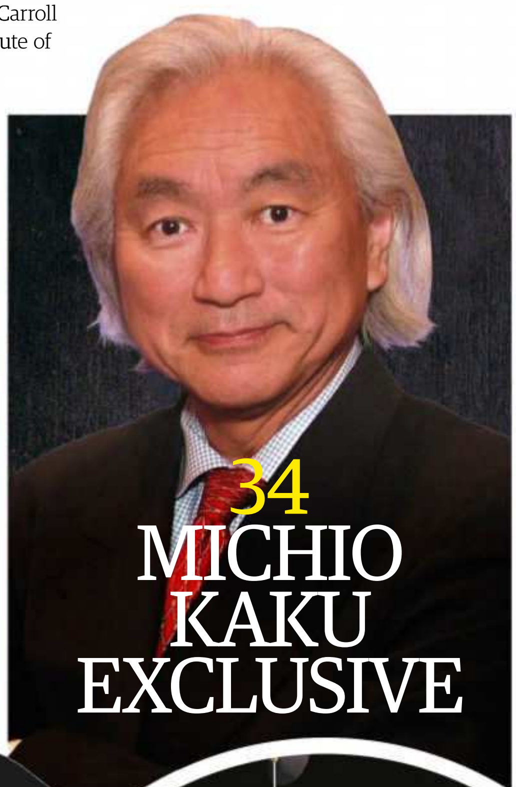
...RSES?



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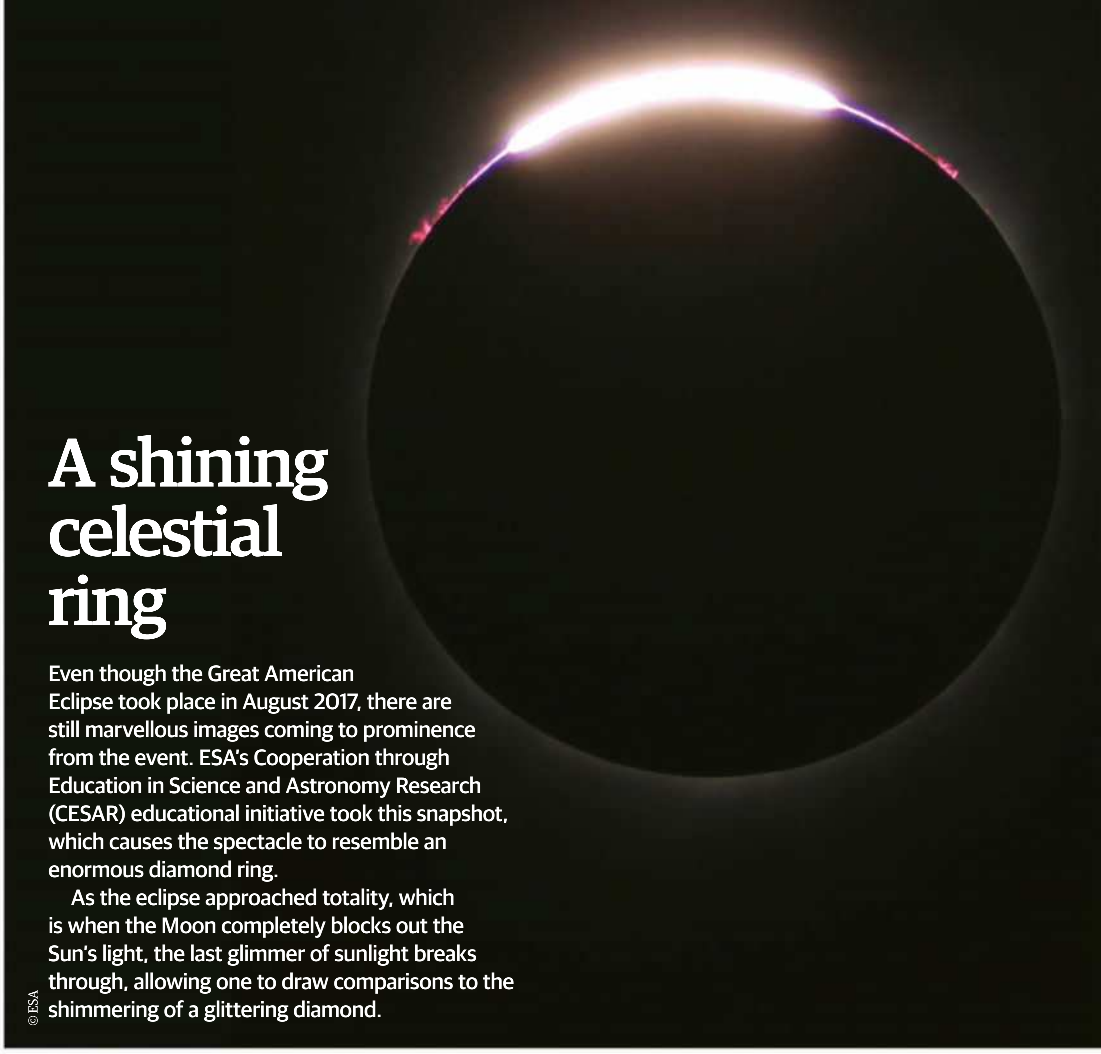
LAUNCH PAD
YOUR FIRST CONTACT WITH THE UNIVERSE

Southern star trails above Paranal Observatory

Combining landscapes and stars with long exposures results in some of the best astrophotography images around. Here, one European Southern Observatory photographer Petr Horálek took this fine star trail shot of the Southern Hemisphere sky over the Paranal Observatory in Chile.

Other than the obvious motion of the stars, there was also the appearance of a shooting star cutting across the circular paths. The stars in this hemisphere all rotate around their 'North Star' equivalent, known as Sigma Octantis. However, this star is much fainter and far less noticeable than Polaris.

© ESO/P. Horálek



A shining celestial ring

Even though the Great American Eclipse took place in August 2017, there are still marvellous images coming to prominence from the event. ESA's Cooperation through Education in Science and Astronomy Research (CESAR) educational initiative took this snapshot, which causes the spectacle to resemble an enormous diamond ring.

As the eclipse approached totality, which is when the Moon completely blocks out the Sun's light, the last glimmer of sunlight breaks through, allowing one to draw comparisons to the shimmering of a glittering diamond.

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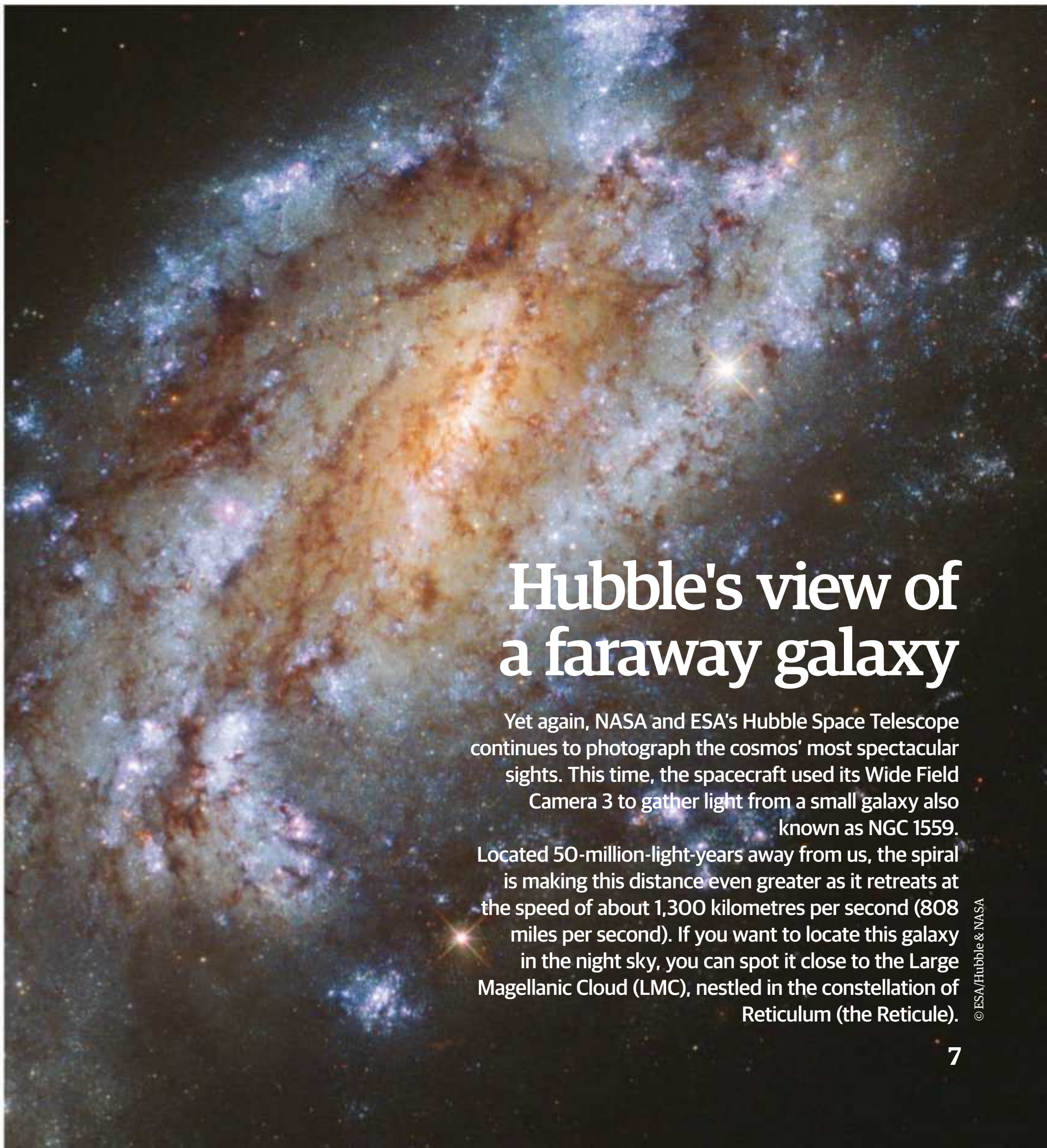
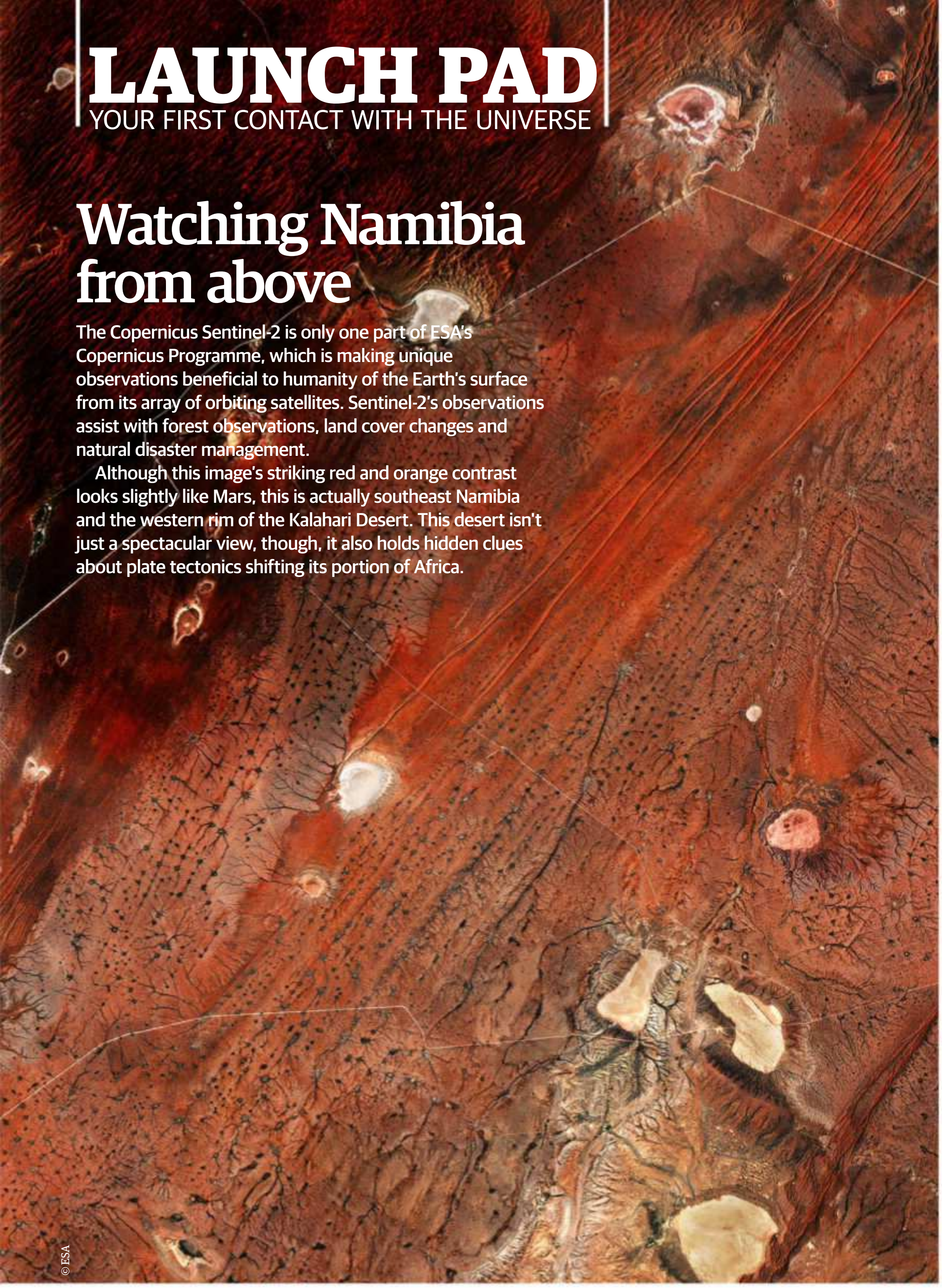


Hubble's view of a faraway galaxy

Yet again, NASA and ESA's Hubble Space Telescope continues to photograph the cosmos' most spectacular sights. This time, the spacecraft used its Wide Field Camera 3 to gather light from a small galaxy also known as NGC 1559.

Located 50-million-light-years away from us, the spiral is making this distance even greater as it retreats at the speed of about 1,300 kilometres per second (808 miles per second). If you want to locate this galaxy in the night sky, you can spot it close to the Large Magellanic Cloud (LMC), nestled in the constellation of Reticulum (the Reticule).

© ESA/Hubble & NASA



Watching Namibia from above

The Copernicus Sentinel-2 is only one part of ESA's Copernicus Programme, which is making unique observations beneficial to humanity of the Earth's surface from its array of orbiting satellites. Sentinel-2's observations assist with forest observations, land cover changes and natural disaster management.

Although this image's striking red and orange contrast looks slightly like Mars, this is actually southeast Namibia and the western rim of the Kalahari Desert. This desert isn't just a spectacular view, though, it also holds hidden clues about plate tectonics shifting its portion of Africa.

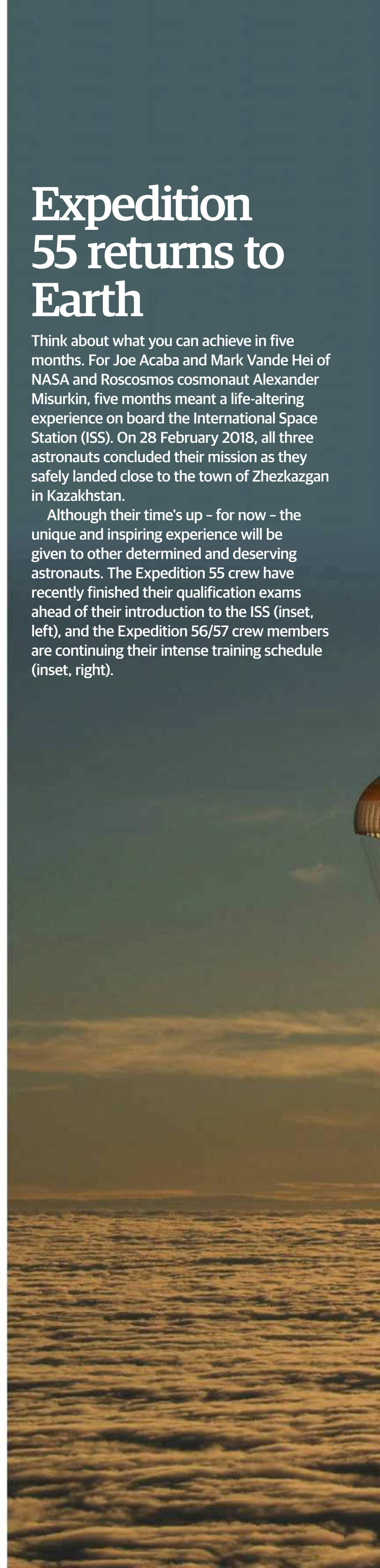
© ESA

Five faces of Phobos

Mars has two moons, Phobos and Deimos, and they are relatively tiny in comparison to our own natural satellite. Phobos is only 22 kilometres (14 miles) in diameter and, of the pair, orbits the closest to the Red Planet.

ESA's Mars Express spacecraft was able to image Phobos in five different channels using its High Resolution Stereo Camera. The centre image used the nadir channel, the images to the left and right used two photometry pathways and the outer two shots used the stereo channels. These shots will allow astronomers to make improved models of Mars' closest and largest satellite.

© ESA



Expedition 55 returns to Earth

Think about what you can achieve in five months. For Joe Acaba and Mark Vande Hei of NASA and Roscosmos cosmonaut Alexander Misurkin, five months meant a life-altering experience on board the International Space Station (ISS). On 28 February 2018, all three astronauts concluded their mission as they safely landed close to the town of Zhezkazgan in Kazakhstan.

Although their time's up – for now – the unique and inspiring experience will be given to other determined and deserving astronauts. The Expedition 55 crew have recently finished their qualification exams ahead of their introduction to the ISS (inset, left), and the Expedition 56/57 crew members are continuing their intense training schedule (inset, right).

Venus photobomb

The European Southern Observatory's Paranal Observatory in Chile is a sublime optical-infrared observatory, and here it is showing off one of the Very Large Telescope's (VLT) auxiliary telescopes.

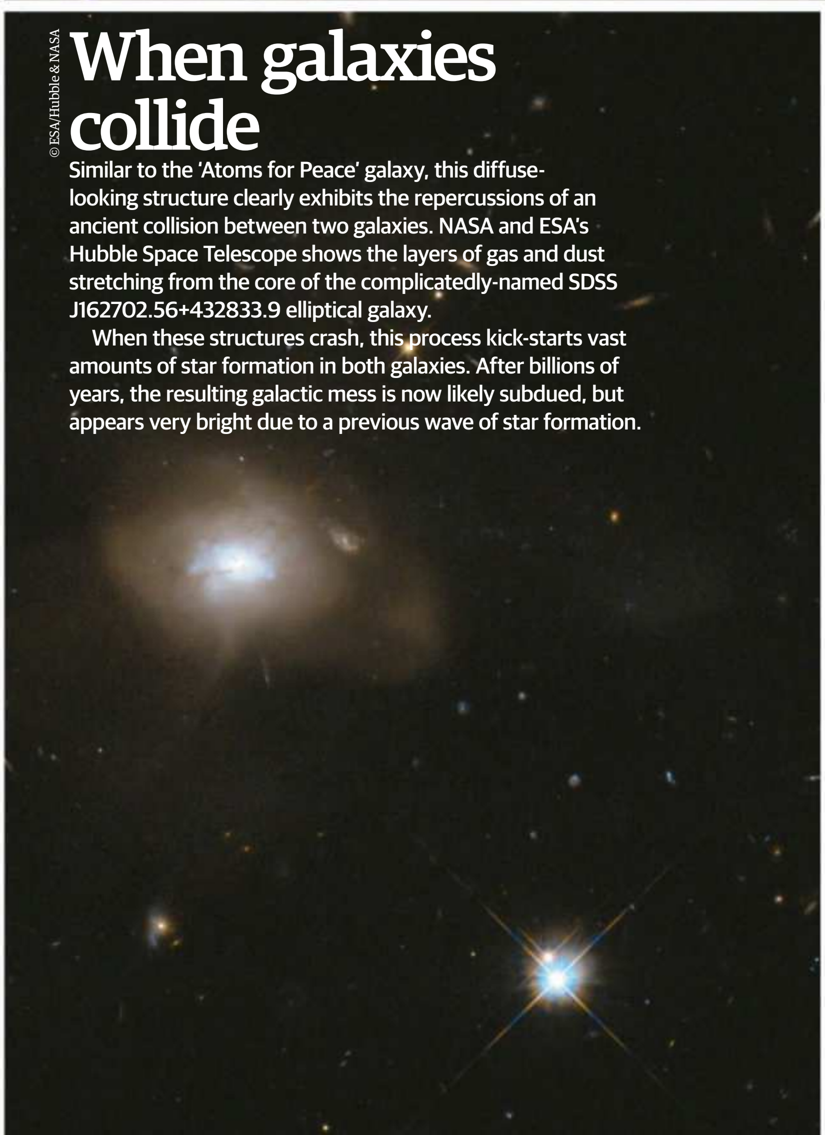
As sunset approaches and the sky changes from blue to orange, ending in black, the VLT prepares itself for a night of celestial spying by opening its dome. Already appearing above it is our planetary neighbour, Venus. The exceedingly-bright world, hovering over the industrious Paranal Observatory at Chilean twilight is arguably a truly awe-inspiring sight.

© P. Horálek / ESO

Galaxies for Peace

The significant merger of two small galaxies occurred roughly a billion years ago. What we see now is this beautiful structure nicknamed the 'Atoms for Peace' galaxy, formally dubbed NGC 7252. This galaxy looks like its namesake; the structure of an atom, with the nucleus of protons and neutrons being the luminous galaxy at its core. Meanwhile, the shells of electrons are the layers of gas stretching outwards. 'Atoms for Peace' arises from when President Eisenhower made his famous speech in 1953 declaring nuclear power a catalyst for global peace.

© NASA & ESA



© ESA/Hubble & NASA

When galaxies collide

Similar to the 'Atoms for Peace' galaxy, this diffuse-looking structure clearly exhibits the repercussions of an ancient collision between two galaxies. NASA and ESA's Hubble Space Telescope shows the layers of gas and dust stretching from the core of the complicatedly-named SDSS J162702.56+432833.9 elliptical galaxy.

When these structures crash, this process kick-starts vast amounts of star formation in both galaxies. After billions of years, the resulting galactic mess is now likely subdued, but appears very bright due to a previous wave of star formation.

A planet is born!

The formation of planets is a precarious process. The formation of Earth was largely a game of chance, and only by observing the formation of other planets can we get a clearer picture of our history.

Astronomers have used the European Southern Observatory's Atacama Large Milimeter/submilimeter Array (ALMA) to image the fascinating protoplanetary disc of AS 209, which is 410-light-years away from Earth. The rings rising from the structure are particularly fascinating, as they show astronomers how gas and dust is shaped in the early ages of a young star, before any planets can be made.

© ESO / NAOJ / NRAO / D. Fedele

Astronomers detect the first stars born after the Big Bang

Researchers discover an ancient signal that helps pinpoint the moment stars lit up the universe for the first time

Astronomers peering back in time have detected a faint radio signal from the very first stars, finally answering the question of when such celestial bodies burst into life. It would appear that the earliest stars began turning on their light some 180 million years after the Big Bang. If the findings regarding the timing of the so-called Cosmic Dawn are confirmed then it will have huge implications for our scientific understanding of the cosmos.

Scientists have long known that in the immediate aftermath of the Big Bang, the universe was cold, dark and featureless. It was filled with hydrogen and helium and there was much background radiation, known as Cosmic Microwave Background. But the question of how and when the universe transitioned from darkness to light has long troubled the best of minds. This is why a team led by Judd Bowman of Arizona State University sought to detect the earliest stars.

They based their work on the theory that gravity caused the densest regions of hydrogen gas to coalesce and form compact clouds in the wake of the universe's birth. Some of these eventually collapsed inwards, forming massive, blue, yet short-lived stars and, as they emitted their ultraviolet light into the dark areas that lay between them, the energy signature of the hydrogen atoms changed.

The atoms began to absorb radiation from the Cosmic Microwave Background at a frequency of 1.4 gigahertz, leaving an indelible mark. Understanding this led to a long-held idea that the absorption should be detectable – that it was possible to look for a dip in brightness of the background radiation. The problem is the radio waves have stretched because they have travelled for so long. Other signals also interfere.

Finding the right one was no mean feat, but Dr Bowman and his team made a breakthrough after 12 years of experimental effort. They used a table-sized ground-based radio spectrometer: Experiment to Detect the Global EoR Signature (EDGES). Based at the Murchison Radio-astronomy Observatory in Western Australia, where interference is low, the team says it was able to measure the average radio spectrum of all of the astronomical signals received across much of the Southern Hemisphere sky.

The eureka moment came after the team extended their search to lower frequencies in 2015. The instrument was then able to detect a tiny 0.1 per cent dip in the wavelength. "We see this dip most strongly at about 78 megahertz," affirms Alan Rogers, co-author of the study. "And that frequency corresponds to roughly 180 million years after the Big Bang. In terms of a direct detection of a signal from the hydrogen gas itself, this has got to be the earliest." If true – and the team spent two years checking that the finding was not caused by instrumental effect and noise – it means those early stars formed a staggering 13.6-billion-years ago.

Yet that is not the end of the team's findings. Since the size of the dip was twice as large as expected, the study also discovered that the universe prior to the formation of the first stars was far colder than astronomers had originally believed. It points to the universe at that stage being -270° Celsius (-454° Fahrenheit) – less than half the expected temperature. Rennan Barkana of Tel Aviv University says this points to the first evidence that dark matter, which he says is composed of low-mass particles, siphoned off energy from normal matter in the early universe. It means the hydrogen gas was losing heat to dark matter. "The first stars in the universe turned on the radio signal, while the dark matter collided with the ordinary matter and cooled it down," Professor Barkana says.

This makes the discovery of the first stars even more important than initially imagined. "If Barkana's idea is confirmed, then we've learned something new and fundamental about the mysterious dark matter that makes up 85 per cent of the matter in the universe, providing the first glimpse of physics beyond the standard model," said Dr Bowman. Indeed, because it suggests that dark matter is interacting with hydrogen, it turns the theory that dark matter is made up of weakly interacting massive particles on its head.

As such, Dr Bowman is not about to stop there. "Now that we know this signal exists, we need to rapidly bring online new radio telescopes that will be able to mine the signal much more deeply," he explains, referring to instruments such as the Hydrogen Epoch of Reionization Array (HERA) and the Owens Valley Long Wavelength Array (OVRO-LWA). The next step is to improve the performance of the instruments to learn more about those early stars. It is also crucial that the findings are independently confirmed.

What the experts say...

"It is unlikely that we'll be able to see any earlier into the history of stars in our lifetimes. This project shows that a promising new technique can work and has paved the way for decades of new astrophysical discoveries."

Judd Bowman, Arizona State University School of Earth and Science Exploration

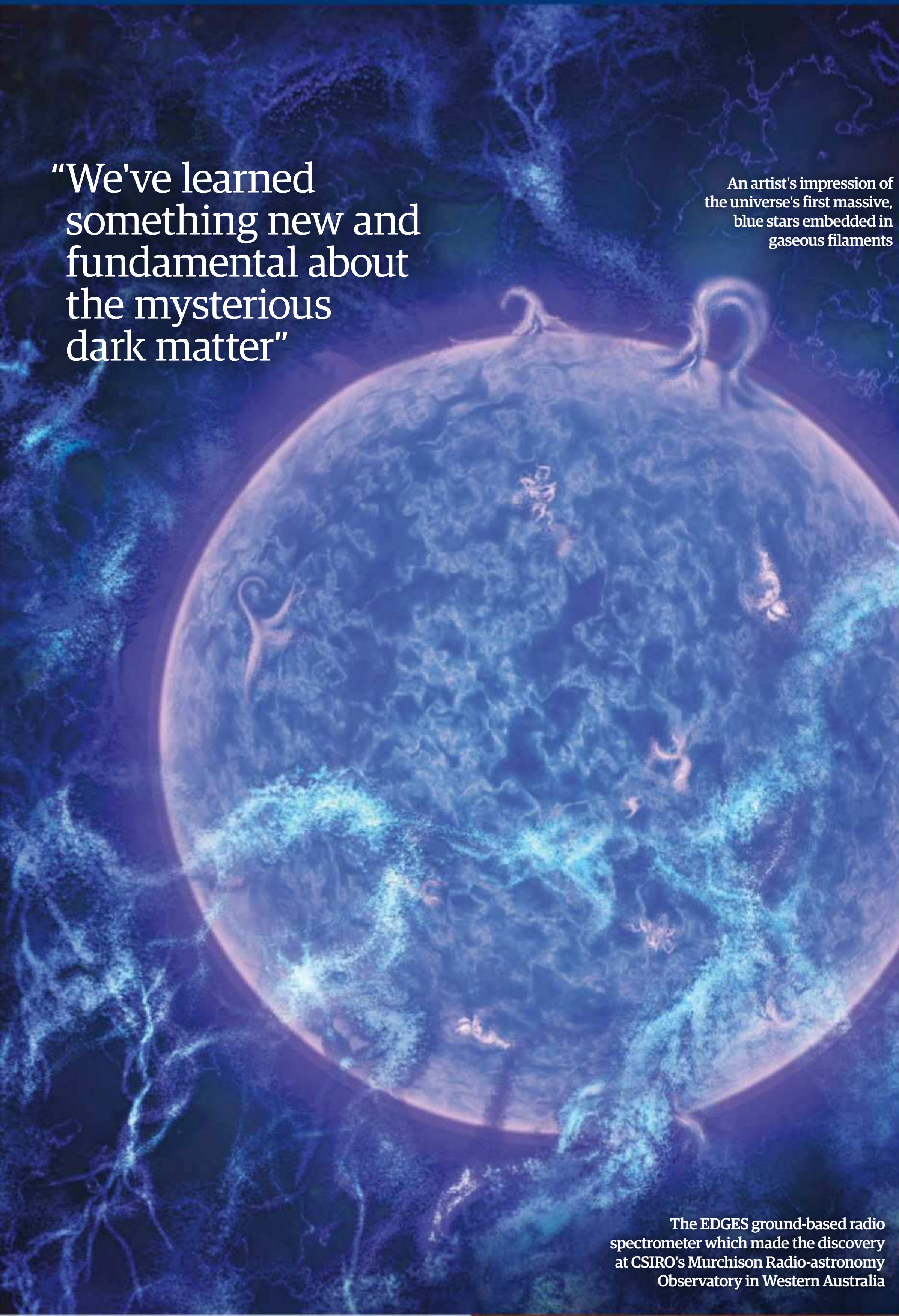
"The unexpected depth of 21cm absorption is exciting because it should make spatial fluctuations in this signal easier to observe. These fluctuations can tell us about variations in density in the early universe, which seed the formation of cosmic structure."

Andrew Robertson, Institute for Computational Cosmology, Durham University

"This surprising signal indicates the presence of two actors: the first stars, and dark matter. The first stars in the universe turned on the radio signal, while the dark matter collided with the ordinary matter and cooled it down. Extra-cold material explains the strong radio signal."

Rennan Barkana, Raymond & Beverly Sackler Faculty of Exact Sciences, Tel Aviv University

"We've learned something new and fundamental about the mysterious dark matter"



An artist's impression of the universe's first massive, blue stars embedded in gaseous filaments

The EDGES ground-based radio spectrometer which made the discovery at CSIRO's Murchison Radio-astronomy Observatory in Western Australia

"Larger instruments are under construction that will be able to map this signal in greater detail, but those other experiments were conceived before knowing for sure if a detection could ever be made. This discovery gives them a specific signal to look for."

Peter Kurczynski, Advanced Technologies and Instrumentation, National Science Foundation

Space News in Brief

Europa mission gets budget cut

US Congress has offered the Europa Clipper mission $264.7 million – down on the $425 million NASA asked for last year. There are now growing concerns that it won't be enough to launch the spacecraft into orbit around Jupiter, especially given its been brought forward to 2025.

Saturn's wind mystery solved?

Saturn's winds can reach breathtaking speeds of up to 1,770 kilometres (1,100 miles) per hour, but scientists now reckon they have a good idea how they take shape. A 43-inch-wide rotating pot holding several hundred litres of water was heated from below, causing the warmed-up water to rise. Surface water, meanwhile, was cooled by evaporation and sank.

Universe expanding faster than expected

Precise measurements taken by the Hubble Space Telescope appear to show the cosmos is expanding much faster than expected. A discrepancy has emerged between the data and scientific predictions of the universe's trajectory, with dark energy or dark matter being put forward as a potential explanation.

Deviating rocket puzzle finally solved

The European heavy-lift launch vehicle Ariane 5 deviated from its expected flight path in January, losing control with ground staff. An investigation has discovered it had been fed with the wrong coordinates. This issue did not affect the rocket's ability to reach orbit, but it will need to use more fuel.

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The JWST will help with discoveries on the Red Planet

New space telescope to study Mars

The James Webb Space Telescope is set to target the Red Planet to reveal fresh secrets and potential signs of life

NASA's James Webb Telescope will be used to study how Mars turned from a wet to a dry planet in a bid to discover fresh clues about its past and present habitability. The space agency says the telescope will be able to take a snapshot of the entire disk of Mars at once, allowing astronomers to see how much water escapes into space.

Webb, which is seen as the successor to Hubble, will watch the normal-water-to-heavy-water ratio (H_2O to D_2O) during the different seasons and gather data at different times and locations. It will test the theory that D_2O – which includes a heavy hydrogen called deuterium – remains on Mars, while the lighter molecules are lost to space. As NASA explains, a skewed ratio of H_2O to D_2O on Mars would be indicative of how much water has escaped.

"We can also determine how water is exchanged between polar ice, the atmosphere and the soil," says Geronimo Villanueva of NASA's Goddard Space Flight Center. When Webb targets Mars in 2020 as part of a Guaranteed Time Observation project, it will offer unprecedented resolution and sensitivity. "Observations of Mars will test Webb's capabilities in tracking moving objects across the sky," says Stefanie Milam, also of Goddard.

Webb is set to be launched in 2019. Care will have to be taken not to swamp the telescope's delicate instruments with light, but its work in detecting small differences in light wavelengths will follow years of studies into the loss of Martian water and the planet's changing environment.

The superflare shone at a factor of 1,000 for just ten seconds

Superflare scorches hope of life on our closest exoplanet

Intense radiation from Proxima Centauri casts huge doubts for life

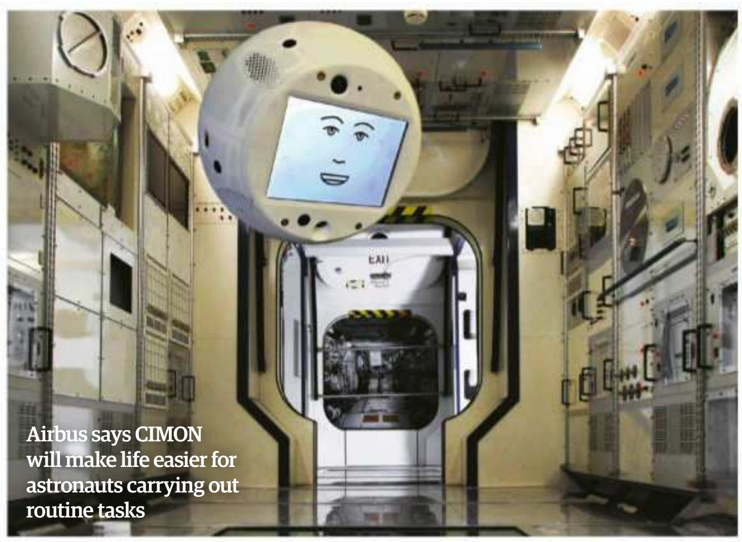
Astronomers are dismayed to discover that Proxima Centauri has bombarded the exoplanet Proxima b with radiation. A stellar flare in March last year was ten-times brighter than our Sun's largest flares, and as Proxima b is far closer to its star than the Earth is to ours, it all but destroys the chance of the planet supporting alien life.

The flare was discovered using data from the Atacama Large Millimeter/submillimeter Array (ALMA), with the whole event, also involving smaller flares, lasting for less than two minutes. That was enough, however, to allow scientists to reach a sobering conclusion. "Over the billions of years since Proxima b formed, flares like this one could have evaporated any atmosphere or ocean and sterilised the surface, suggesting that habitability may involve more than just being the right distance from the host star to have liquid water," says Meredith MacGregor, an astronomer at the Carnegie Institution for Science.

It does, however, mean that astronomers can hone the search for extraterrestrial life and make more accurate future predictions based on whether intensive, violent radiation is likely to be felt. For now, we can most likely rule out Proxima b, even though it's in its star's habitable zone.

A 'flying brain' is heading for the ISS

Airbus has been working on a clever robotic virtual assistant for the International Space Station



Airbus says CIMON will make life easier for astronauts carrying out routine tasks

The Space Station is getting a new crew member, but it's not quite what you'd expect. Instead, the Crew Interactive Mobile Companion (CIMON) is a floating drone that not only presents a friendly face to human astronauts, but displays data readouts wherever it may be needed.

Its makers are calling it "a kind of flying brain" and it's not too dissimilar to the intelligent companions seen in various sci-fi films and TV shows. In fact, it's on the same lines as HAL in *2001: A Space Odyssey* and Holly in *Red Dwarf*. Developed by Airbus and IBM and made of 3D-printed plastic and metal, it is the size of a medicine ball and it weighs around five kilograms.

The drone will use Watson artificial intelligence to help the ISS crew solve problems while engaging verbally with them and flagging up technical problems. "In short, CIMON will be the first AI-based mission and flight assistance system," said Manfred Jaumann, head of microgravity payloads at Airbus, with a statement from the company adding it will become a "genuine colleague".

CIMON is currently being tested by ESA astronaut Alexander Gerst who is set to return to the ISS for the Horizon's mission between June and October. He will take the drone with him and make use of a selected range of capabilities, but the medium-term aim is to examine the group effects that can develop during long missions, such as to the Moon or Mars.

ISSET PRESENTS

MISSION DISCOVERY™

Join astronaut Michael Foale at the Space & STEM Summer School this July and launch your very own experiment into space

> MEET > LEARN > DESIGN > LAUNCH

This summer, join British-American astronaut Michael Foale at King's College, London for ISSETs flagship 'Mission Discovery' Space & STEM Summer School from 8 to 13 July 2018.

Mission Discovery invites students aged 14 to 18 years old to spend the week working in teams with NASA astronauts, rocket scientists and King's College London professors. The aim of the week is to design an experiment which will be launched to the International Space Station and conducted by astronauts on board.

Throughout the week, students will hear a variety of talks from the entire Mission Discovery team based on team building, leadership, space, the sciences and personal development.

With help from our brilliant NASA role models, students will finish the week by presenting their idea to ISSET's judging panel, and one experiment will be selected and launched to the ISS on a SpaceX Falcon 9 rocket.

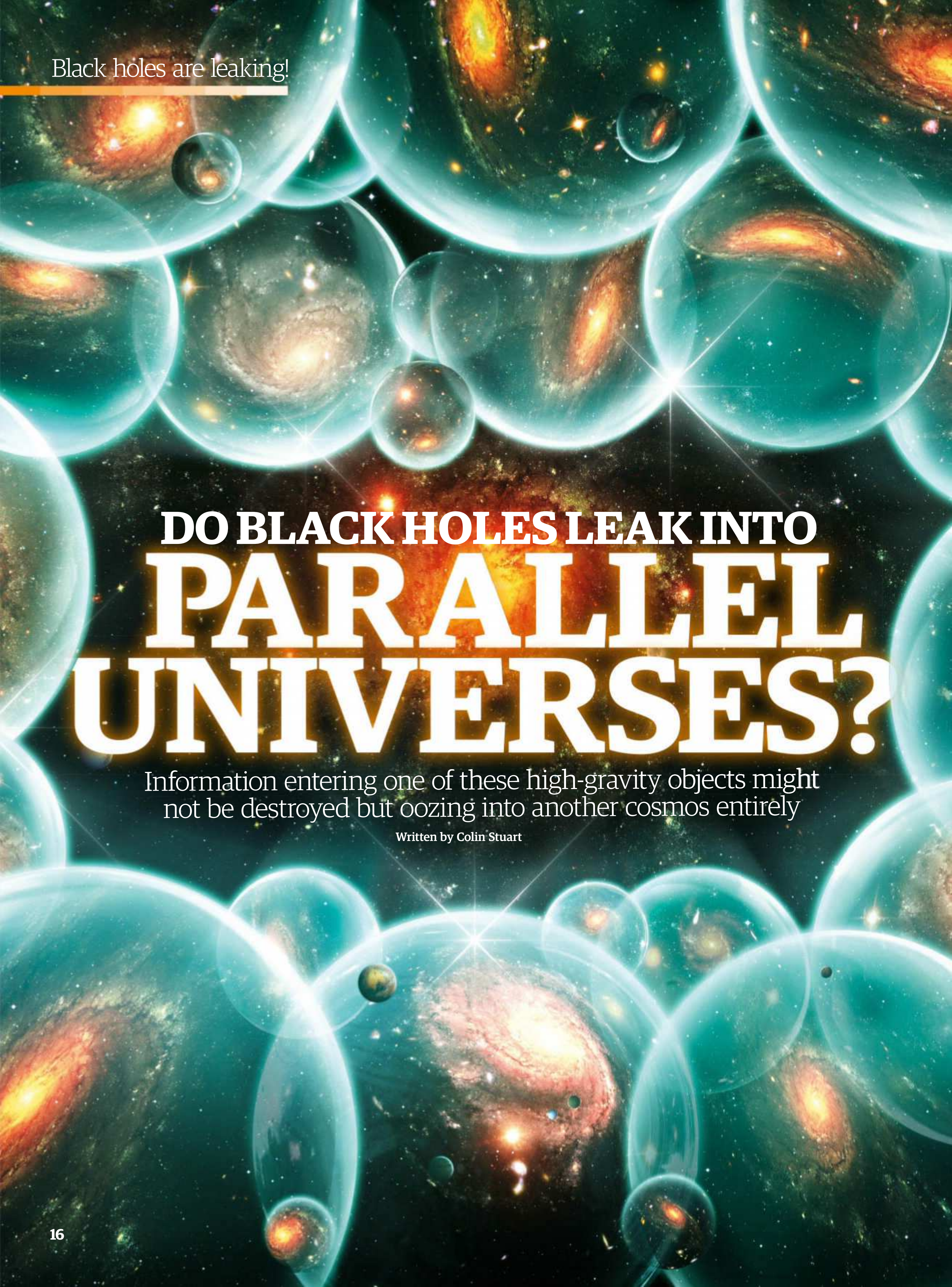
Mission Discovery was launched in 2012. Since then we have worked with 12 NASA astronauts, held programmes in four continents for over 5,000 students sending 17 experiments into space on five different rockets, with a further seven experiments scheduled to launch over the next year.

Mission Discovery winners have appeared on NASA TV, BBC, ITV and Channel 4, along with numerous press publications internationally. If you're looking for a challenge, which could change your life and build your future, this is it!

"I am delighted to be back at Mission Discovery. With this program, students are getting a rare opportunity to participate in something that is unimaginable for most young people. It will not only help them gain knowledge about space, but also enhance their self-belief and capabilities. I would have loved this opportunity as a student, who knows where this journey will take them."
STEVEN SWANSON, NASA ASTRONAUT & ISS COMMANDER

Astronaut Michael Foale is the first British-American to fly into space

"Mission Discovery was brilliant; a motivational and inspiring programme that I was thrilled to be a part of. I enjoyed every aspect of the Summer School, from working in teams to produce our experiments, to listening to lectures from astronauts and professors at King's College London."
ELEANOR, GUMLEY HOUSE SCHOOL, MISSION DISCOVERY KCL PARTICIPANT



DO BLACK HOLES LEAK INTO PARALLEL UNIVERSES?

Information entering one of these high-gravity objects might not be destroyed but oozing into another cosmos entirely

Written by Colin Stuart

Invisible, enigmatic and infuriating, black holes are astounding. Formed from the explosive deaths of the most massive stars, they push our very understanding of space and time to its limit. They are regions of such concentrated gravity that escaping from their clutches is impossible for those venturing too close. Once you've crossed the event horizon, you'd have to travel faster than the speed of light to escape but nothing can travel faster than the speed of light. Breach the event horizon and you're doomed to oblivion. What's more, you cannot hail anyone for help.

These monsters are so vexing because at various times they are both big and small. They start as the size of a star, where Einstein's general theory of relativity rules the roost. But, as the core of the dead star collapses to form the black hole, matter is concentrated down into an ever-smaller space. Eventually it moves into a realm dominated by the rules of the super-small - the weird and wonderful world of quantum physics.

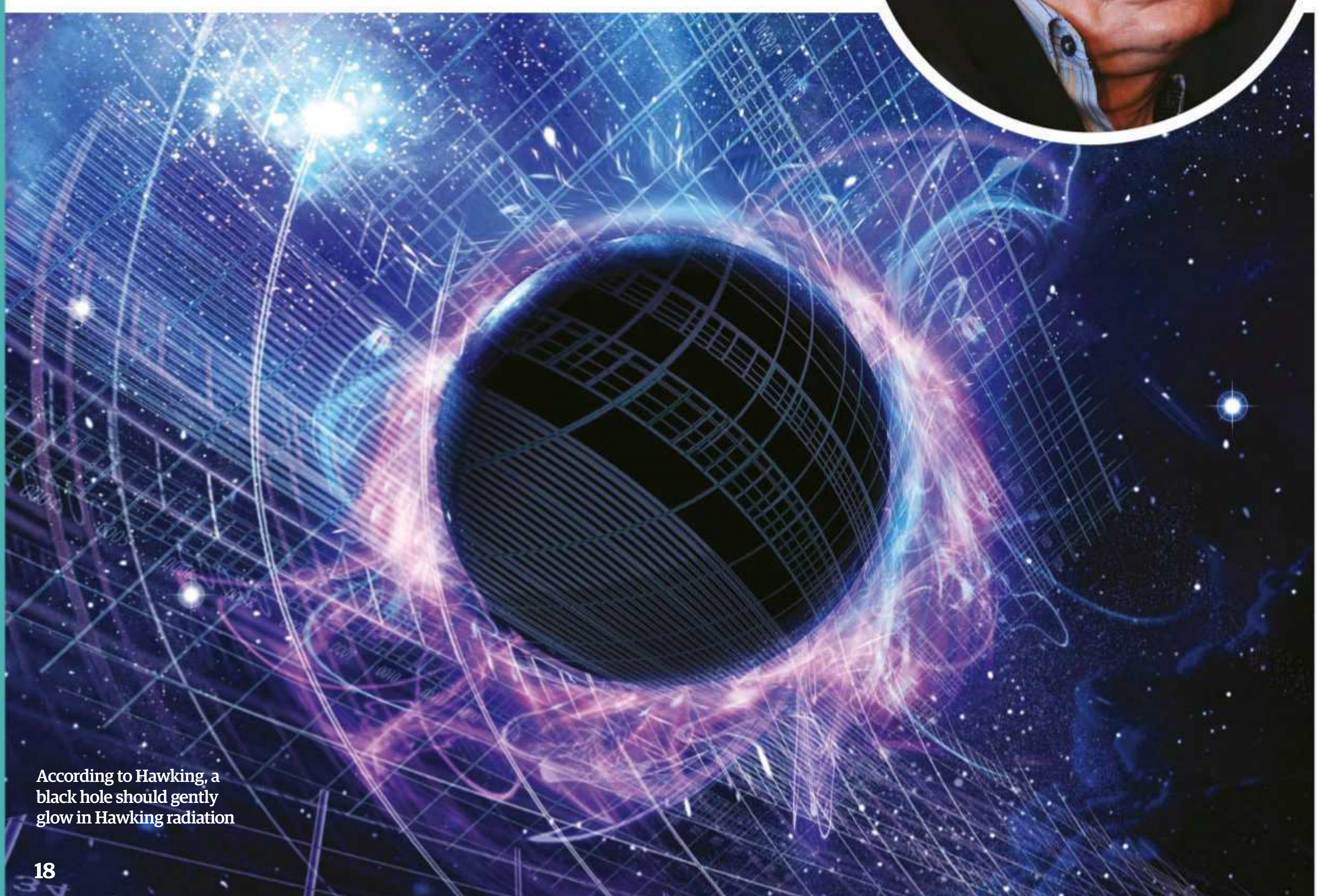
Both of these theories have rightly been lauded for their individual explanatory power. Einstein published his revolutionary theory in 1915 and so far it has passed every test thrown at it with flying colours. The recent discovery of the gravitational waves it predicted was a real triumph. Equally, our modern technological age is built on a thorough understanding of quantum physics. Yet physicists cannot get the two theories to play together nicely. There is no currently accepted theory of "quantum gravity" that combines the two neatly on the same scale. Black holes in particular embarrass us by confronting us with the reality of this dilemma.

One of the most famous attempts to reconcile the two theories with the physics of black holes was provided by Stephen Hawking in 1974. In a well-studied quantum phenomenon, a pair of subatomic particles can simultaneously pop into existence as long as they disappear again very quickly. Hawking imagined this happening right on the event horizon of a black hole. One particle is doomed, the other is free to escape. They can never be reunited, meaning a black hole must slowly lose energy to its immediate environment. According to Hawking, black holes evaporate over time in this way through the emission of one half of these particle pairs - an effect known as Hawking radiation.

However, that idea immediately threw up a problem because his calculations showed that the nature of Hawking radiation depends solely on the mass of the black hole. Yasunori Nomura, a researcher at the Berkeley Center for Theoretical Physics, likes to imagine throwing two books into the void. "One is Shakespeare, the other is Penthouse," he says. While both books contain different words, they both have exactly the same mass. As it only depends on the mass of the black hole, Nomura says the resulting Hawking radiation is identical in both cases. "It looks like the information about whether it was Shakespeare or Penthouse is completely lost," he says. Quantum

Stephen Hawking was one of the first to successfully apply quantum physics to black holes

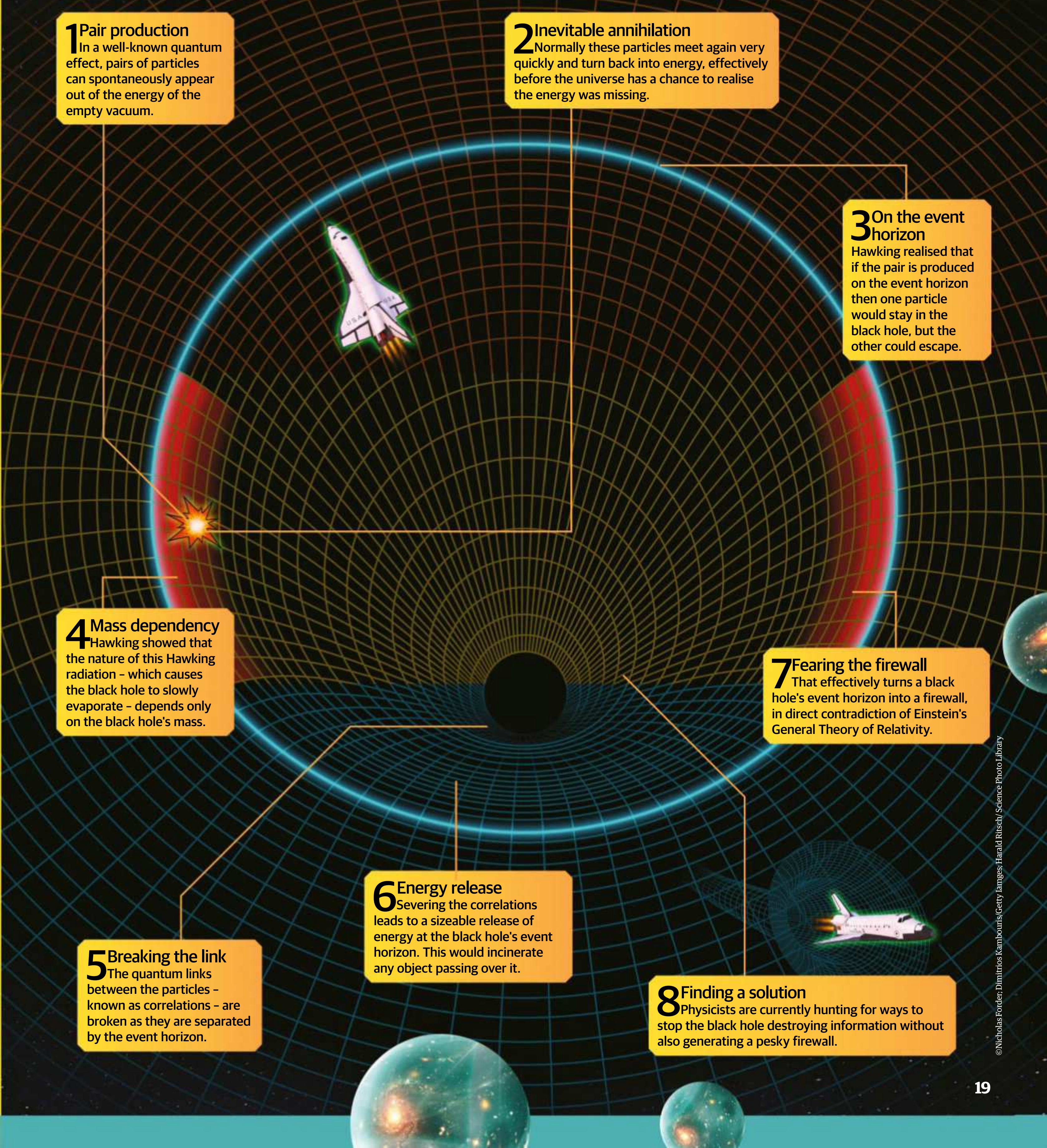
"A black hole can never completely evaporate away. Instead, a minuscule husk would always remain"



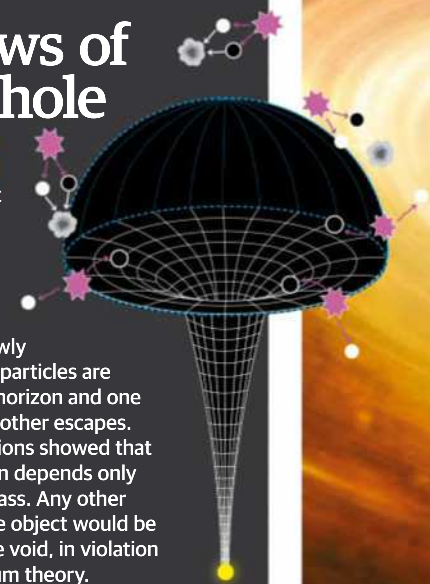
According to Hawking, a black hole should gently glow in Hawking radiation

Theories of a black hole

Physicists have devised a wide range of ideas for what happens to information entering these high-gravity objects

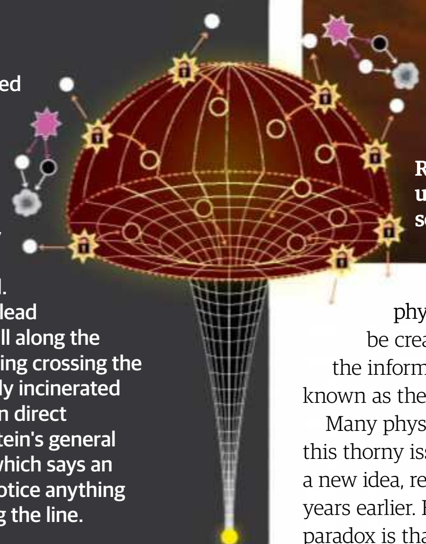


Our views of a black hole



Traditional view

Originally we thought nothing could escape from a black hole. Then, in 1974, Stephen Hawking argued that a black hole should slowly evaporate as pairs of particles are created at the event horizon and one is swallowed and the other escapes. However, his calculations showed that this Hawking radiation depends only on the black hole's mass. Any other information about the object would be completely lost to the void, in violation of the rules of quantum theory.

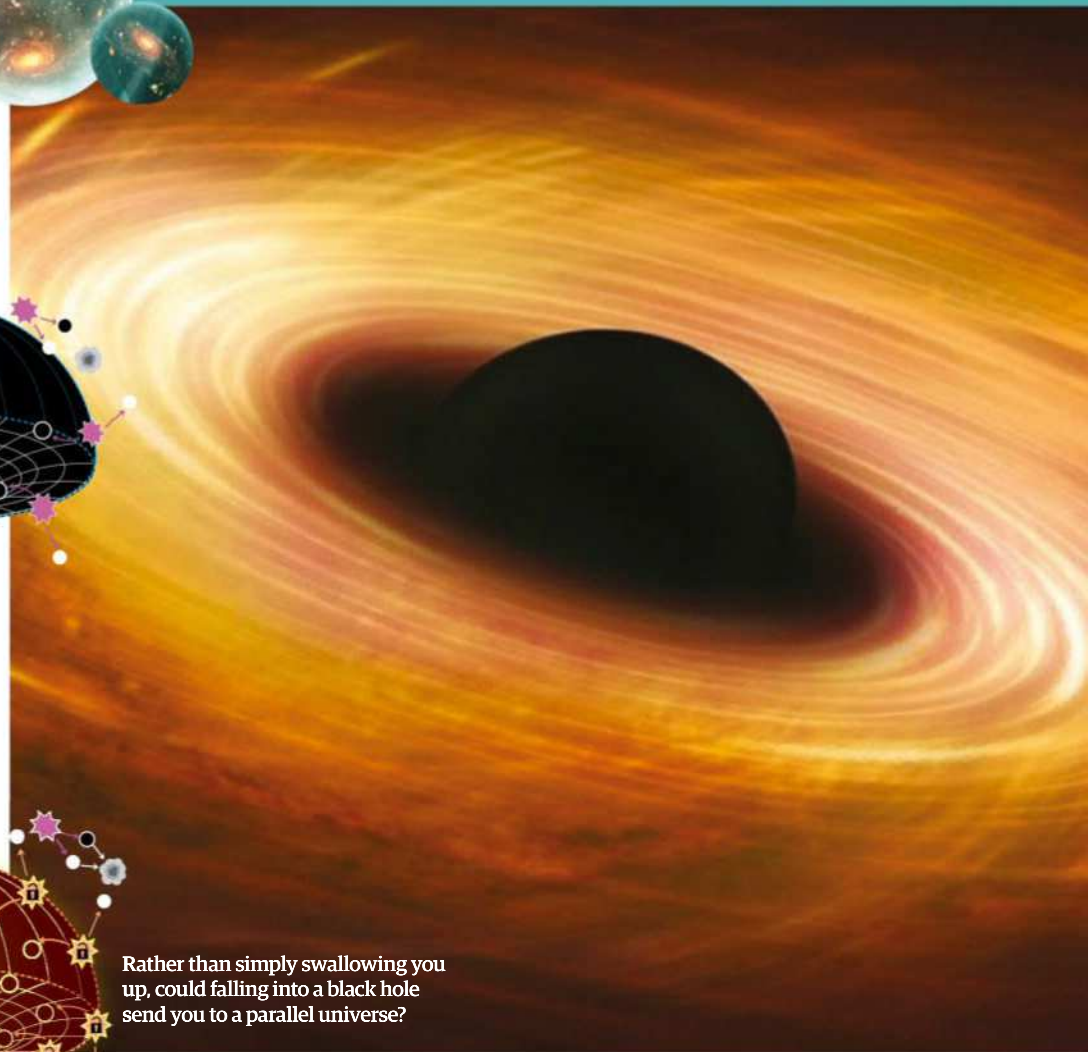


Firewall view

Later, theorists realised that this 'information paradox' could be resolved if the quantum link between the two particles – a property called entanglement – is suddenly severed. However, this would lead to a spike in energy all along the event horizon. Anything crossing the line would be instantly incinerated in a 'firewall'. This is in direct contradiction to Einstein's general theory of relativity, which says an observer shouldn't notice anything special when crossing the line.

Parallel universes view

Some physicists argue that both the information and firewall paradoxes go away if you think of black holes from the viewpoint of the Many Worlds interpretation of quantum theory. It says that every quantum event (such as the creation of a particle pair at the event horizon) splinters the universe into multiple copies – or branches – where all possible outcomes play out. Information is preserved across all branches and Einstein's rule about a smooth passage over the event horizon only applies to each individual branch.



Rather than simply swallowing you up, could falling into a black hole send you to a parallel universe?

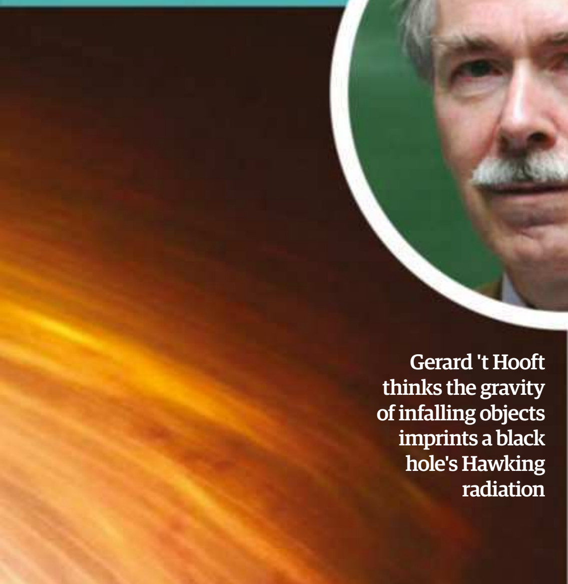
physics says that information cannot be created or destroyed. So where does the information go? This problem has become known as the 'Black Hole Information Paradox'.

Many physicists have wrestled with how to solve this thorny issue. In 2015, Hawking himself detailed a new idea, re-exploring the notion he'd had 40 years earlier. His radical solution to the information paradox is that the information contained within the two books never actually makes it into the black hole. "I propose that the information is stored not in the interior of the black hole as one might expect, but on its boundary, the event horizon," he said at a conference in Sweden on Hawking radiation held that year. According to Hawking, information about three-dimensional objects falling in ends up encoded as a two-dimensional hologram on the event horizon. Later, outgoing Hawking radiation re-delivers this information back into the universe. Given enough time, someone would, in principle, be able to recover the information contained within the books. Hawking would go on to tell the conference that black holes are not the eternal prisons they were once thought to be.

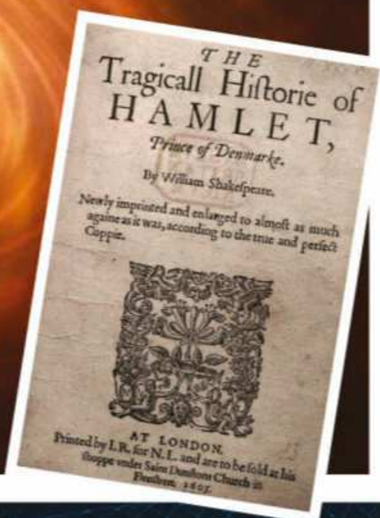
Nobel prize-winning physicist Gerard 't Hooft has another idea. An object crossing the event horizon will begin to feel dramatic changes in its gravitational field. Hawking radiation will be affected by these gravitational changes and so carry out with it information about what the incoming object was. However, both Hawking and 't Hooft's ideas have a significant snag: quantum physics not only forbids information from being destroyed, it also outlaws it being duplicated. The object falling in will carry one copy of its information, while another either sits as a hologram on the event horizon or is carried outwards by Hawking radiation. The mystery is far from solved.

Other researchers found a less drastic ray of hope when they discovered a way that Hawking radiation might preserve the information contained within objects added to the black hole without the need for holograms or duplicates. However, they could only get this to happen by dramatically severing the quantum link between the two particles that initially created the Hawking radiation. Cutting the cord would lead to a sudden burst of energy. With this process happening all along the event horizon, crossing over it would be like entering hell. You'd soon be incinerated by what physicists have a dubbed a 'firewall'. This creates a new paradox. Einstein's general theory of relativity forbids anything special happening when you cross over the event horizon. Like the Earth's equator, it is a purely mathematical line. Why should you be set alight just because you pass from the equivalent of

> "The information is stored not in the interior of the black hole, but on its boundary, the event horizon" **Stephen Hawking**



Gerard 't Hooft thinks the gravity of infalling objects imprints a black hole's Hawking radiation


THE
Tragicall Hiſtorie of
HAMLET,
Prince of Denmarke.
By William Shakeſpeare.
Newly imprinted and enlarged to almoſt as much againe as it was, according to the true and perfect Coppie.
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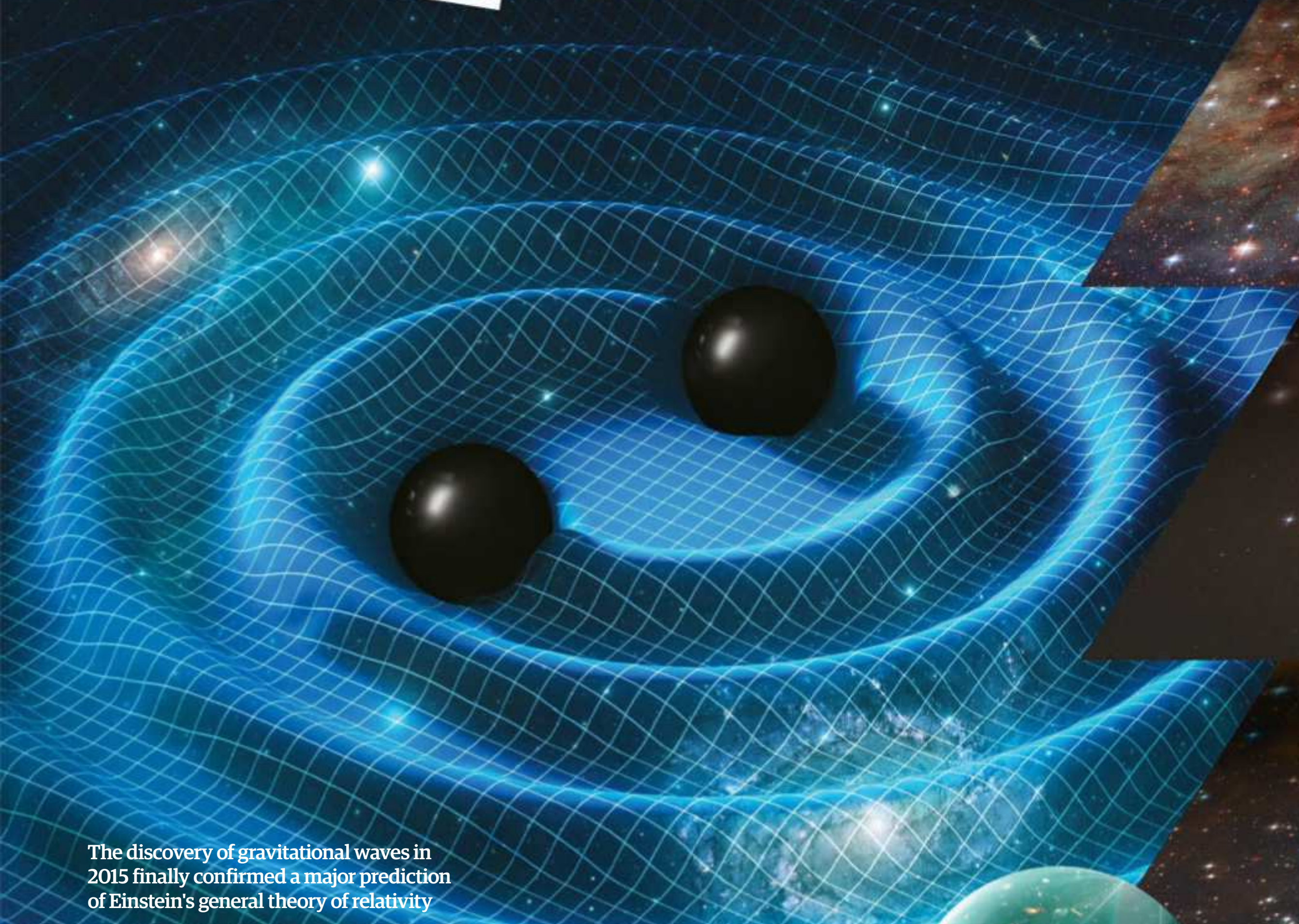
one hemisphere into another? Physicists call this 'The Firewall Paradox'. Applying quantum physics to black holes suggests the existence of Hawking radiation. At first that implied information can be destroyed – The Information Paradox – unless crossing the event horizon singes you into a ball of smoke – The Firewall Paradox.

"I'm just not comfortable with this idea," says Ana Alonso-Serrano at the Max Planck Institute for Gravitational Physics in Germany. She's been looking for an alternative way out and now believes she may have found one. "You don't need a firewall," she says. To come to this conclusion, Alonso-Serrano looked at some of the current models for how quantum gravity might work. She specifically investigated something called the Generalised Uncertainty Principle (GUP), which says the more you know about a black hole's size the less you know about its energy. Her work shows that more and more Hawking radiation would be given off as the black hole evaporates, changing the amount of information it carries away. "Information isn't lost – it is hidden in the Hawking radiation," she says. Alonso-Serrano admits that her solution "is not a complete resolution" to the problem, but it has the potential to eliminate the pesky firewall. Her work also shows that a black hole can never completely evaporate away. Instead, a minuscule husk would always remain.

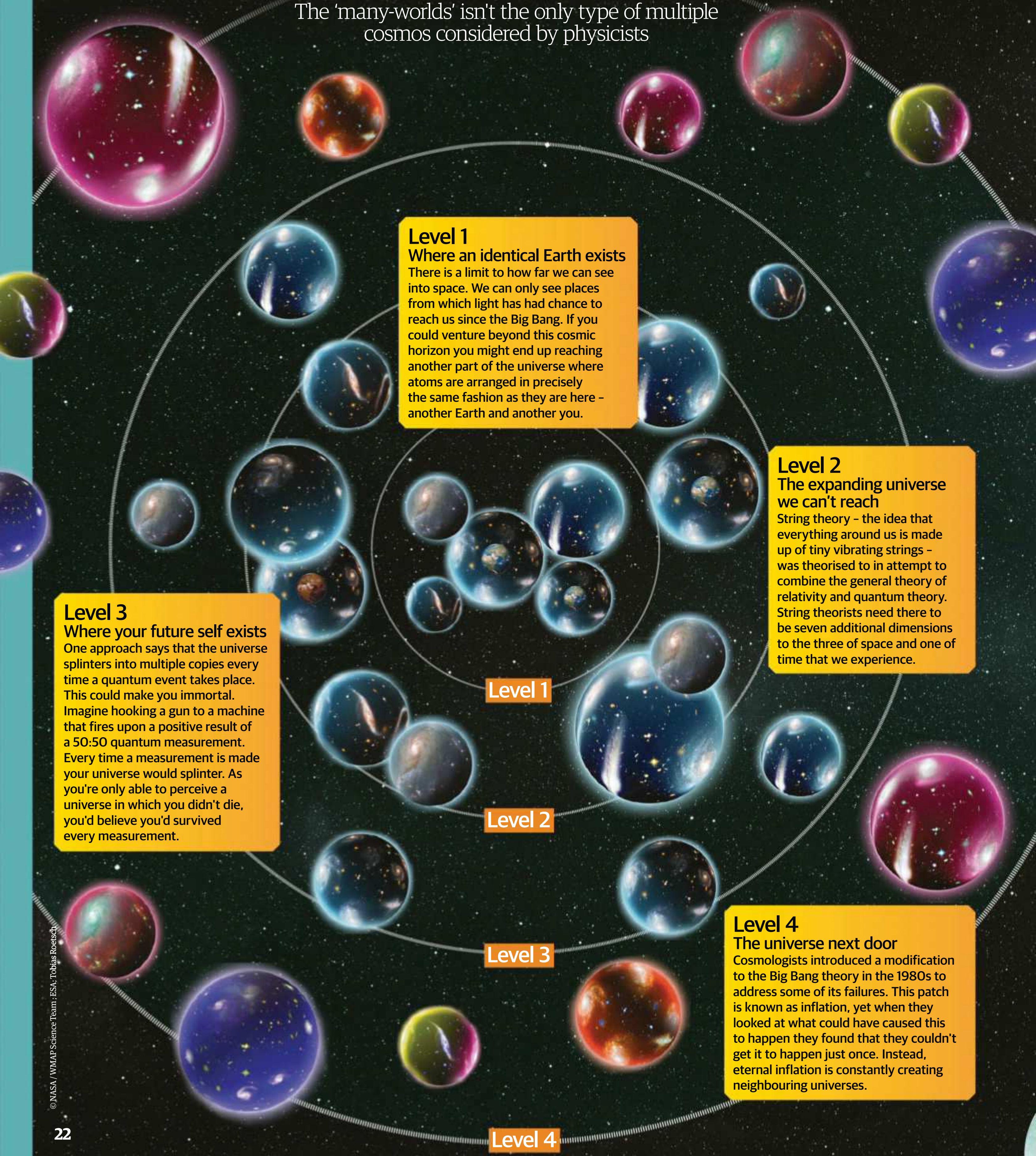
It's possible that every quantum event fractures the universe into copies



The discovery of gravitational waves in 2015 finally confirmed a major prediction of Einstein's general theory of relativity

What happens in parallel universes?

The 'many-worlds' isn't the only type of multiple cosmos considered by physicists



Level 1
Where an identical Earth exists

There is a limit to how far we can see into space. We can only see places from which light has had chance to reach us since the Big Bang. If you could venture beyond this cosmic horizon you might end up reaching another part of the universe where atoms are arranged in precisely the same fashion as they are here – another Earth and another you.

Level 2
The expanding universe we can't reach

String theory – the idea that everything around us is made up of tiny vibrating strings – was theorised to in attempt to combine the general theory of relativity and quantum theory. String theorists need there to be seven additional dimensions to the three of space and one of time that we experience.

Level 3
Where your future self exists

One approach says that the universe splinters into multiple copies every time a quantum event takes place. This could make you immortal. Imagine hooking a gun to a machine that fires upon a positive result of a 50:50 quantum measurement. Every time a measurement is made your universe would splinter. As you're only able to perceive a universe in which you didn't die, you'd believe you'd survived every measurement.

Level 4
The universe next door

Cosmologists introduced a modification to the Big Bang theory in the 1980s to address some of its failures. This patch is known as inflation, yet when they looked at what could have caused this to happen they found that they couldn't get it to happen just once. Instead, eternal inflation is constantly creating neighbouring universes.

Danish physicist Niels Bohr was instrumental in developing the Copenhagen interpretation of quantum theory

Aidan Chatwin-Davies, from Caltech in California, is another theoretical physicist not fond of firewalls. He has recently found an alternative way to abandon a blazing event horizon. He says all we have to do is think of black holes in terms of the many worlds interpretation of quantum physics - an idea first devised by physicist Hugh Everett in the 1950s as an alternative way of thinking about the weird sub-atomic world.

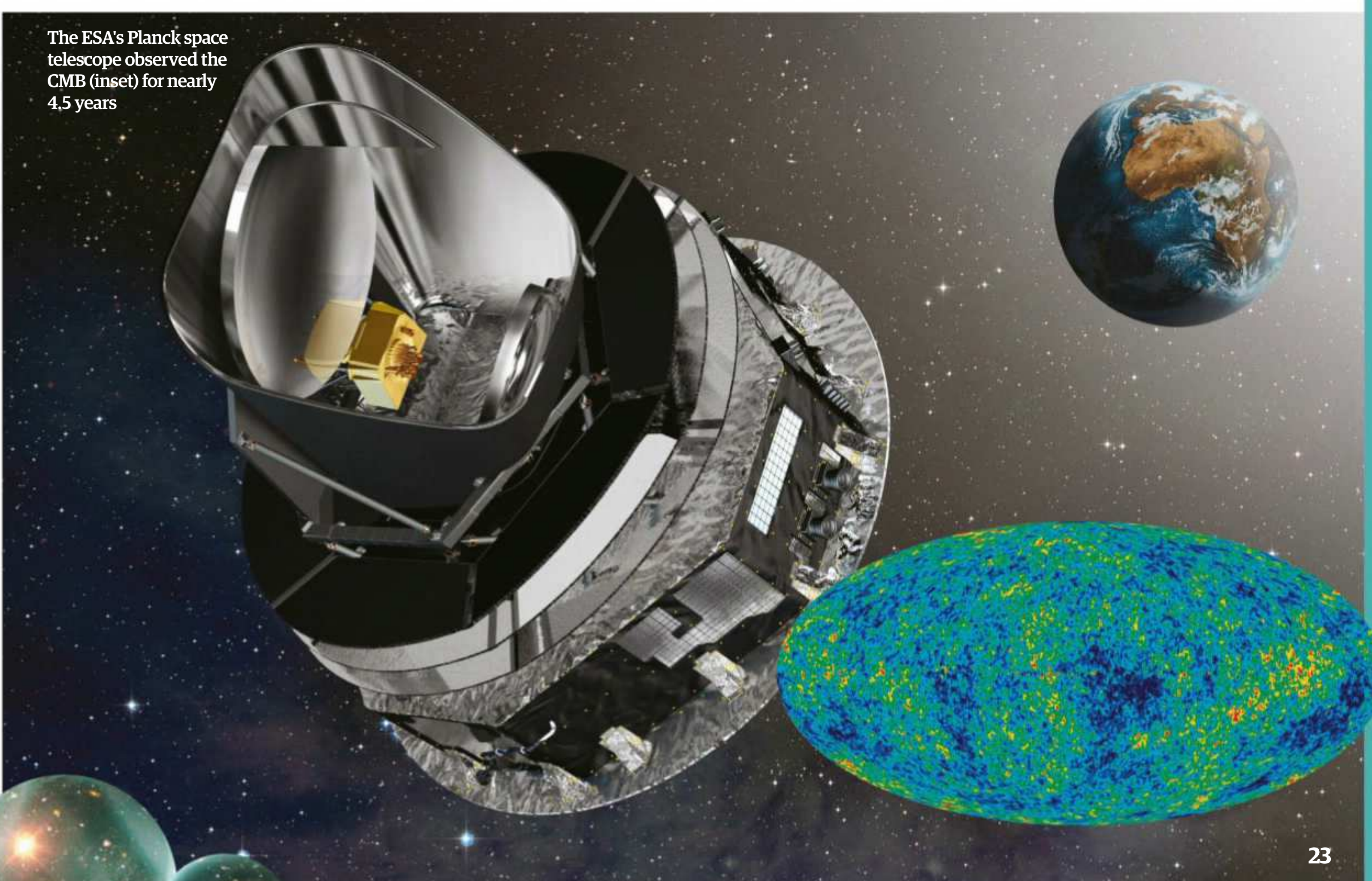
Quantum physics famously says that a particle can be in two places at once, or in two different states simultaneously. The original interpretation of this idea, favoured by Niels Bohr and devised in Denmark, is known as the Copenhagen interpretation. It argues that only once the particle is measured does it 'decide' which state to appear in. However, fellow physicist Erwin Schrödinger devised his famous Schrödinger's Cat thought experiment to show up holes in this argument. The eponymous feline is trapped in a sealed box with a hammer and a vial of poison. Whether or not the hammer falls to crack the vial depends on the outcome of a measurement on a quantum particle. The Copenhagen interpretation says that the particle is simultaneously in both states at once until the measurement is made. That means the hammer falls and doesn't fall and the cat is alive and dead until the particle is measured. But why does the act of measuring force nature to choose? Everett's alternative 'many-worlds' picture was to suggest that it doesn't – both outcomes occur. The universe splits into two distinct versions (or branches) – one where the cat lives and another where it perishes.

"If you are trying to describe the formation and evaporation of a black hole truly quantum gravitationally then you would expect multiple versions of the black hole," says Chatwin-Davies, just like there are two versions of the cat. The implications for the information paradox are profound. "If you're sitting around monitoring the Hawking radiation coming out of a black hole you should expect to see a loss of information," he says. That's because you're limited to one of the many branches the black hole now exists in. The information about an infalling object isn't destroyed, it is simply shared out across the many branches of reality. Throw *Hamlet* into a black hole and Act I may emerge in this universe's Hawking radiation, but Act II in another.

Nomura agrees. "Focus on one world and clearly you cannot recover all the initial information," he says. What effect does this have on the firewall? "The statement that you have to go smoothly into a black hole applies only to each branch of the many worlds," says Nomura. "Whereas the rules about quantum information apply to the whole set of worlds." According to Nomura, the Firewall Paradox results from confusing these differences. Chatwin-Davies is on the same page. Comparing the two "is like comparing apples and oranges," he says.

So, as with many times in the history of physics, answering one question has thrown up several others. Information falling into a black hole may be imprinted as a hologram on the event horizon and carried back into space by Hawking radiation. It could be that severing the link between the quantum particles responsible for Hawking radiation incinerates you to a crisp as you enter, or that information could be hidden in the Hawking radiation after all. Finally, it could even be possible that information falling into a black hole is shared out among the many versions of reality that splinter off as a black hole evolves. Until we crack the elusive code of quantum gravity, it is hard to know who is right.

"If you're monitoring the Hawking radiation from a black hole you should expect to see a loss of information" **Aidan Chatwin-Davies**



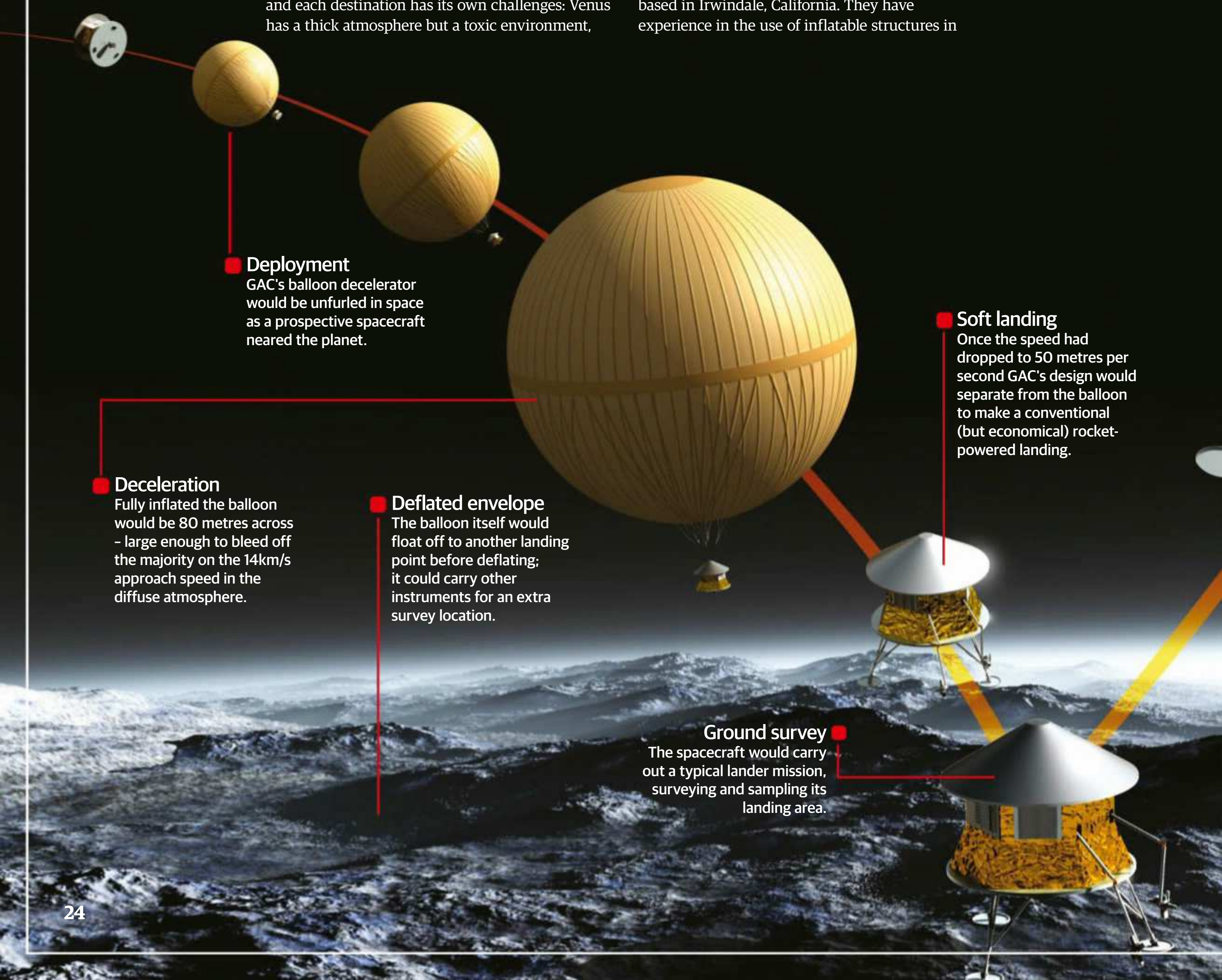
The ESA's Planck space telescope observed the CMB (inset) for nearly 4,5 years

Pluto hopper

A NASA project is working on a new way to slow down planetary spacecraft to enable an ingenious hopping dwarf planet mission

Planetary exploration missions are always a trade off of technology and cost. The very first ones just flew past or crashed into their targets, then came stationary soft landers and an increase in the use of wheeled rovers. If you're visiting a planet you want to explore as much of it as possible but, as the Google Lunar XPrize has demonstrated, it remains prohibitively expensive and challenging to place something on the Moon, let alone on a distant planet. The problem becomes more pronounced the further away the target is, and each destination has its own challenges: Venus has a thick atmosphere but a toxic environment, Mars has lower gravity but hardly any atmosphere to aid braking. Pluto is perhaps the ultimate challenge, being so distant the trip requires the most energy of any in the Solar System. It took New Horizons, one of the fastest-ever space probes, over nine years just to get there just to fly past. However, Pluto has an advantageous combination of atmospherics and gravity that a team from the Global Aerospace Corporation (GAC) are hoping to exploit to open up Pluto for exploration.

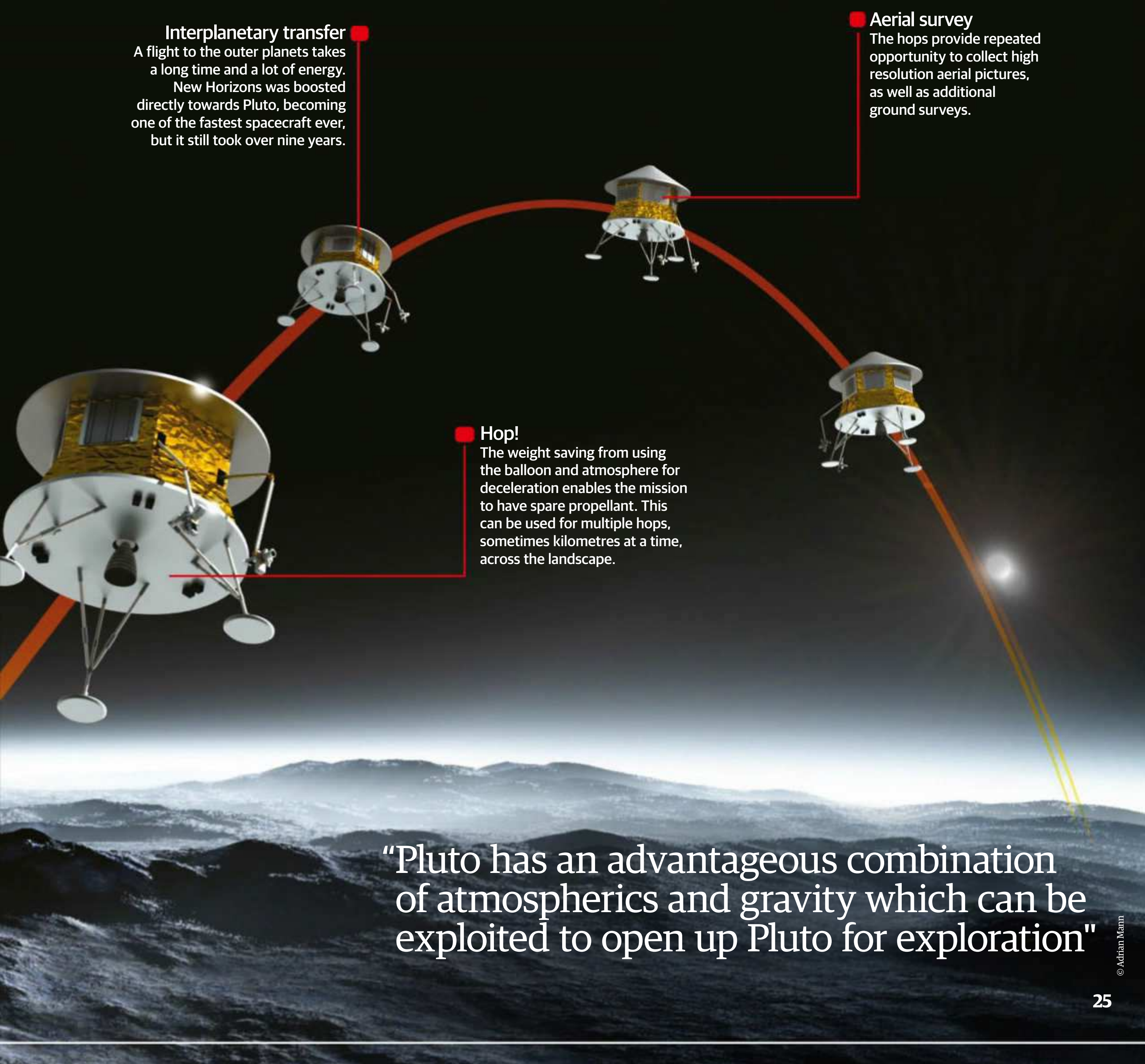
GAC are an aerospace engineering company based in Irwindale, California. They have experience in the use of inflatable structures in



space, which they are using to design an ingenious spacecraft braking system. Although Pluto's surface pressure is only ten millionths of Earth's, its low gravity (6.7 per cent of the Earth) means the atmosphere stretches out a long way from the planets surface. It stretches to about 1,600 kilometres (1,000 miles), or 135 per cent of the radius of the planet – Earth's atmosphere is in the region of 12 or so per cent of its average radius. GAC have engineered Earthly balloons, inflatable space habitats and drag sails for satellites, and plan to efficiently deliver a payload to Pluto's surface with a balloon decelerator that expands in space to something like the dimensions of a football pitch. Despite a likely approach speed of about 14 kilometres (8.7 miles) per second, the huge, lightweight cross section of the balloon should enable a spacecraft to gently decelerate into the atmosphere, needing less than 3.5 kilograms of propellant for the final soft touchdown.

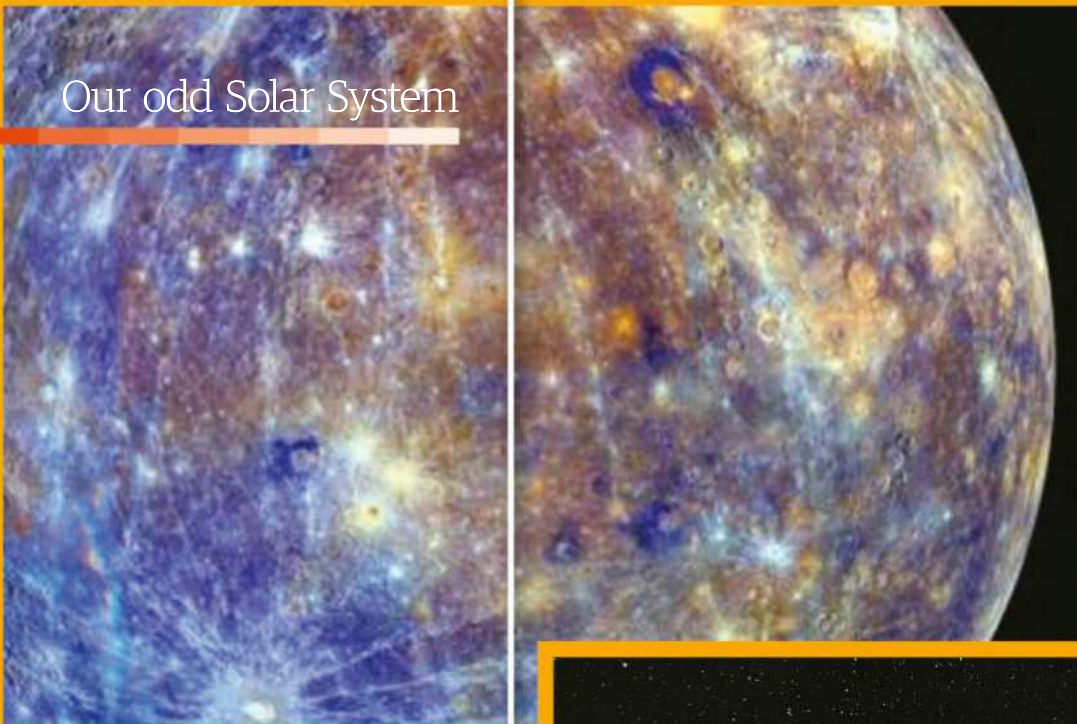
Exploiting the in situ resource of the atmosphere to land almost for 'free' would free up valuable payload space for a local propulsion system. GAC have a spectacular plan to reuse the rocket propulsion that the craft has to have anyway. After making its initial soft landing and investigating the area, GAC's design will fire up its engine with the propellant not needed for landing and launch itself off across the landscape in a series of hops. In this way it would be able to collect data from a number of landing sites, at different heights through the atmosphere and take aerial photographs.

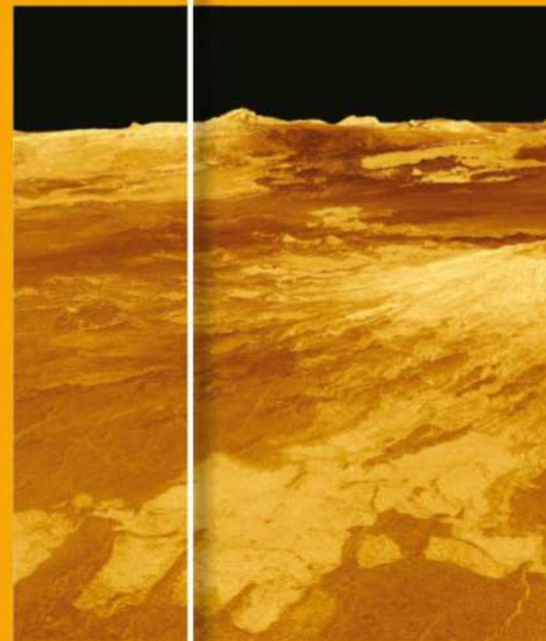
Although in its early stages, GAC propose testing sub-scale versions of the system packed into a cubesat that could be deployed from the International Space Station. This way, complete craft could be evaluated in Earth orbit before final launch to Pluto. Such an inflatable drag sail could also be useful in helping spacecraft brake into orbit around any body that has an atmosphere. In the future GAC hope to be able to develop a complete mission in collaboration with a NASA centre like JPL or LaRC, within a timeframe between ten to 15 years.



"Pluto has an advantageous combination of atmospherics and gravity which can be exploited to open up Pluto for exploration"

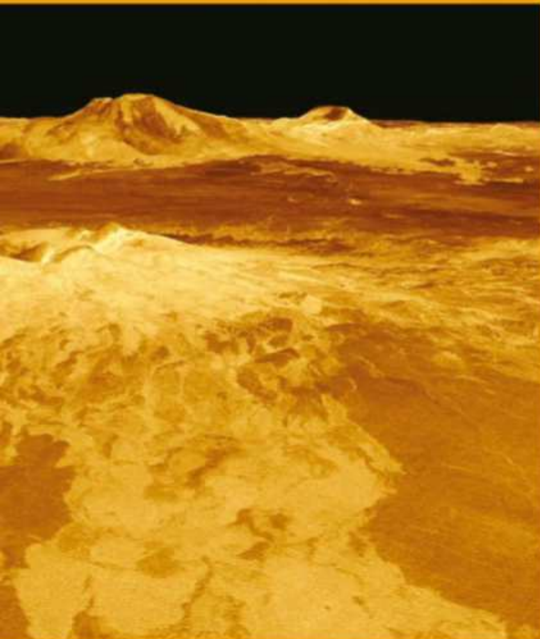
© Adrian Mann





WHY OUR SOL SYST

Studies of other star systems prove there



LAR
TEM IS SO ODD

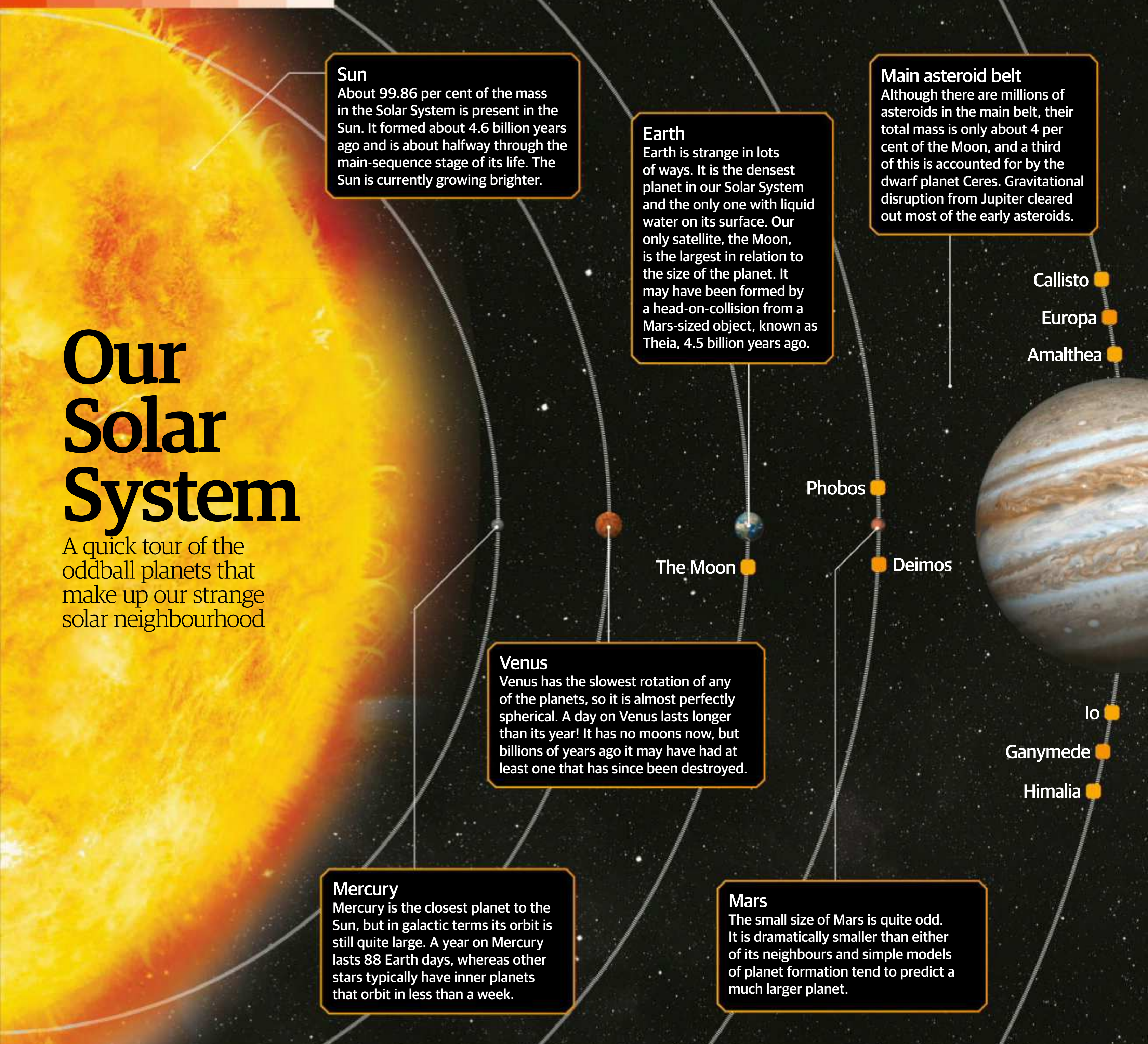
e really is no place like home

Written by Luis Villazon

© NASA/JPL-Caltech; Steven Hobbs

Our Solar System

A quick tour of the oddball planets that make up our strange solar neighbourhood

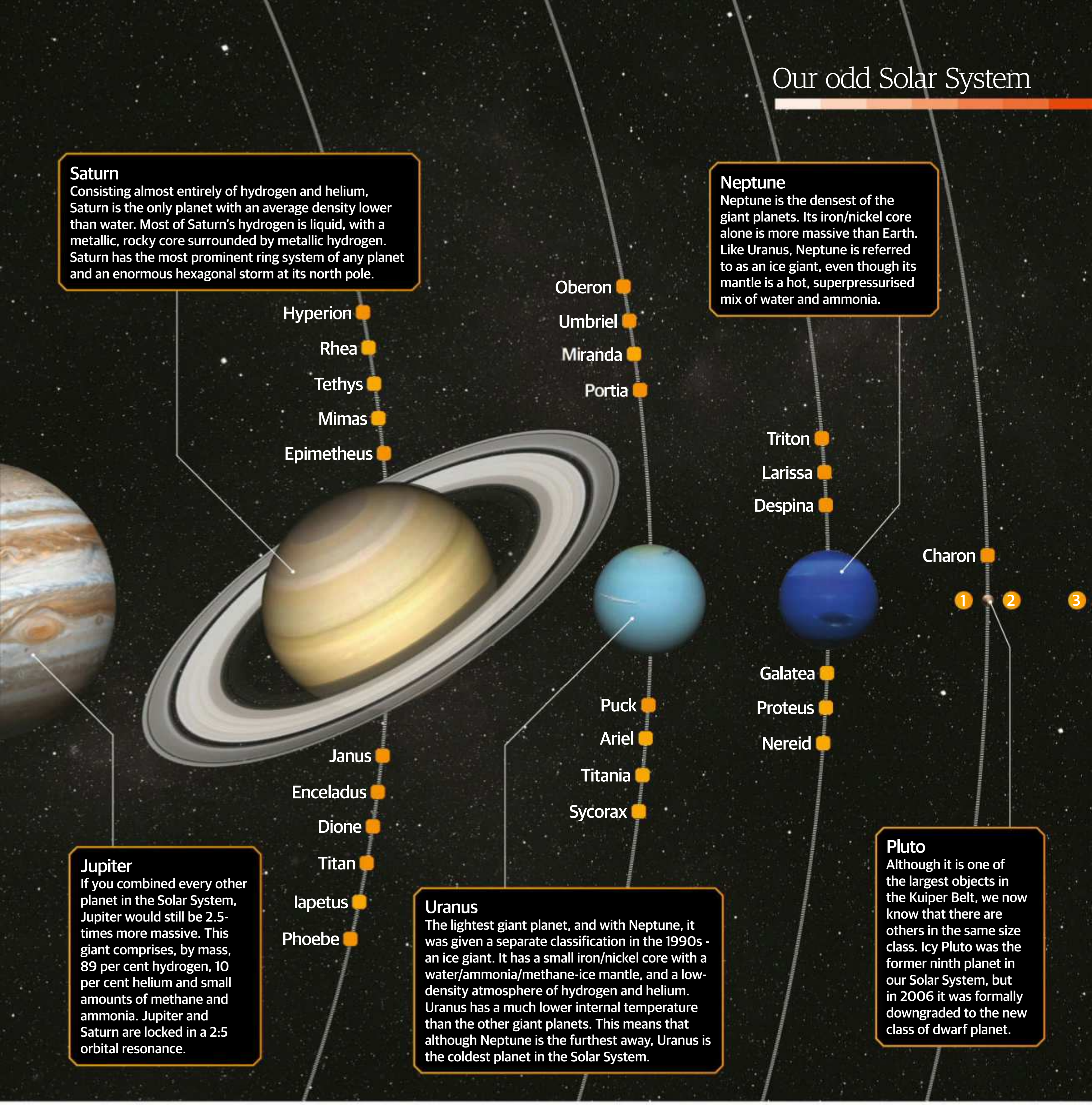


There are at least 100 billion stars in our galaxy, and 2 trillion galaxies in the universe. Results from the Kepler Space Telescope suggests that many of these stars have planets. In view of the number of worlds out there, the Fermi paradox famously asks why we haven't been contacted by other civilisations yet. Perhaps the answer is our Solar System is unique in ways that we hadn't previously considered.

The first planets beyond our Solar System were confirmed in 1992 by looking for stars that wobbled slightly as they were shifted off centre by the gravitational pull of a planet. This method only detects very large planets with very close orbits, so naturally it only found star systems quite different to our own. Then, in 2009 the Kepler Space Telescope began searching for planets by measuring the drop in brightness as a planet transited in front of the star. This is a much more sensitive method, and in nine years has found over 2,300 confirmed exoplanets. Now the California-Kepler Survey has refined the orbital parameters of almost 1,000 of the Kepler planets using ground-based telescopes, and the results announced recently are quite troubling. It's not just that most planetary systems are wildly different to ours. It's the fact that they all follow a distinct and predictable set of rules, and *our* Solar System is the odd one out.

Let's start with the Sun. Our star is a G-type, main sequence star. This is already unusual because around 75 per cent of the stars in the galaxy are M-type red dwarfs, which are smaller and cooler. Even among main sequence stars ours is one of the brightest – it outshines 95 per cent of all the stars in the galaxy. It is also somewhat unusual in being a loner; more than half of all stars are part of binary systems, where two stars orbit each other.

When we look at the planets that the Kepler Survey has found so far, things get even weirder. The most common type of planet in the galaxy by far is the 'superterran' – a rocky planet up to ten-times Earth masses and 2.5-times Earth's radius.



The next most common is the 'sub-Neptune' type; a planet with a hydrogen-helium atmosphere, but is still less than the mass of Neptune. We don't have a single example of either of these planet types in our own system, and planets that do resemble our own in size and composition are rare everywhere else.

The discrepancy becomes even more apparent when you consider the placement of these planets relative to their parent star. We have four small, rocky, inner planets and then four much larger gas giants further out. But almost all the exoplanet gas giants we have found are well into the 'hot zone' of their star (too close for liquid water on the planet surface), even though we used to think that

1 Kuiper Belt
Extending beyond the orbit of Neptune from about 30 to 55AU, objects either miss the orbit of Neptune because they are tilted out of the ecliptic plane, or are locked in an orbital resonance with Neptune. Scientists also believe that Saturn's moon, Phoebe, was captured from the Kuiper Belt.

2 The Scattered Disc
Although it overlaps with the Kuiper Belt at its closest approach to the Sun, the Scattered Disc reaches out twice as far at its furthest point, to around 100AU. Only one of the five dwarf planets, Eris, is found here, and has 27 per cent more mass than Pluto. Most short-period comets originate from here.

3 Oort Cloud
1,000-times further from the Kuiper Belt lies the Oort Cloud. This huge region of space lies between 5,000 and 100,000AU – the very limit of the Sun's gravitational influence. It has never been directly observed, but it is thought to contain several trillion comets, and it is the origin of long-period comets.

gas giants couldn't even form that close. In fact, exoplanets in general appear to orbit their stars much more closely than ours do. Over 93 per cent of all the planets detected by Kepler are inside the hot zone of their star. In our Solar System the only planet that close is Mercury. "We really have nothing interior to Mercury's orbit," says Dr Gregory Laughlin, professor of astronomy and astrophysics at Yale University. "There's zilch. There aren't even any asteroids down there." Kepler-11 on the other hand is a star with five planets orbiting closer than Mercury, and this seems to be the norm.

Of course it is much easier to detect planets with tight orbits in the first place because they block more of the star's light when they transit and they have shorter orbital periods, so it is easier to spot the cyclical pattern as they come round each time. So could this skew in the data simply be a consequence of the kind of planets that Kepler can detect? The lead scientist of one of the California-Kepler Survey studies, Dr Lauren Weiss, says not.

"Kepler was not sensitive to planets beyond about 1AU – the Earth-Sun distance. For this reason, using Kepler alone, we cannot test whether our outer Solar System is unique. However, the statistical properties of Kepler's multi-planet systems show us that our *inner* Solar System is unusual. Most Kepler planetary systems have planets that are very similar in size. In contrast, our terrestrial planets have unusually diverse sizes. Venus is more than twice the radius of Mercury, and Mars is barely half the radius of Earth."

Most exoplanets are just 10 per cent larger or smaller than their immediate neighbours. To check whether Kepler might have missed some planets that would result in more familiar-looking systems, Dr Weiss tried building imaginary star systems with randomly sized planets and then discarded all the ones that wouldn't be detected by Kepler. "The result... looked nothing like the regular patterns in planet size that we observe, so we rejected the null hypothesis. The similar sizes of the planets is astrophysical, not the result of a detection bias."

Another strong statistical pattern that emerged is that planet size increases as .you get further away from the star. This is quite different from our system, where the two largest planets, Saturn and Jupiter, sit in the middle. Very large planets that are more than six-times the size of Earth are already quite rare in the galaxy. Where they occur, it is generally in a system where all the other planets are also large. Another factor is that 90 per cent of

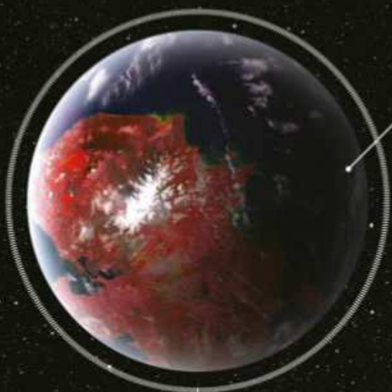
"Planetary systems have planets that are very similar in size. Our terrestrial planets have unusually diverse sizes" **Dr Lauren Weiss**

The Kepler Space Telescope was launched in March 2009 in a Delta II rocket


Most exoplanets orbit much closer to their star than the orbit of Mercury

Worlds just like our own

We've found many exoplanets thanks to advancements in technology, but are they anything like us?



Kepler-442
A K-type main sequence star some 1,115-light-years away. Only one planet has been found around it so far, but it is a 'warm terran' which is estimated to be 2.3-times the mass of the Earth with an orbital period of 112.3 days. Its gravity would feel about 30 per cent greater than Earth's.

Kepler-62
Older, smaller and cooler than our Sun, Kepler-62 has five confirmed planets, ranging in size from a tenth, to over five-times Earth's mass. Two of them, Kepler-62e and Kepler-62f could be in the habitable zone, provided they have just the right atmospheric mix.

Gliese 667
Just 22-light-years away is the triple star system Gliese 667. The smallest of the three stars orbits fairly far away from the other two and may have up to seven planets, including one 3.8-times Earth's mass that lies in the habitable zone.

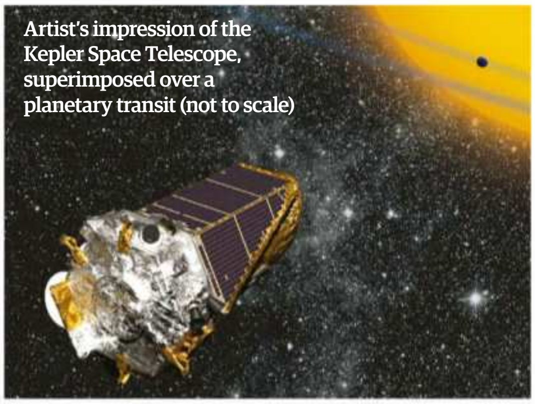
Kepler-438
This red dwarf in the constellation of Lyra, 473-light-years away has just one confirmed planet orbiting it. It was once thought to be the most Earth-like exoplanet; it is just 12 per cent larger than Earth with a similar temperature. However, violent solar flares bathe the planet in radiation every few hundred days.

Kepler-452
A G-type main sequence star, its single planet was the first almost-Earth sized planet that was found in the habitable zone of a star similar to our own. This planet is a warm superterran with five-times Earth's mass and twice the surface gravity. It has a surface temperature that is similar to Earth and a year that is just 20 days longer.

all the gas giants we have found have orbits smaller than Mars'. The few that venture further out are in strongly eccentric orbits. Jupiter is particularly peculiar because it is huge, far away and has an almost perfectly circular orbit. "About one in every 2,000 stars in our galactic neighbourhood is a Sun-Jupiter system," says planetary astronomer Dr Sean Raymond. "Those are about the odds of being picked if you apply to NASA to be an astronaut!"

However, it is the quirkiness of our gas giants that could be the key to understanding all the other strangeness, according to Dr Weiss. "The role of Jupiter and Saturn was likely very important in shaping the Solar System. A complicated dance between Jupiter and Saturn in the early Solar System is often invoked to explain the anomalously small size of Mars. Jupiter and Saturn are also likely responsible for the current orbits of Uranus, Neptune and the Kuiper Belt. Jupiter also might have helped or hindered the delivery of water to Earth by way of comets. Indeed, Jupiter and Saturn might be responsible in some not-yet-quantified way for the rise of life on Earth."

Before the first exoplanets were discovered, theories of planet formation only had to explain our own Solar System. The earliest theories assumed that the planets formed in their current positions. "We used to look at the giant planets and think

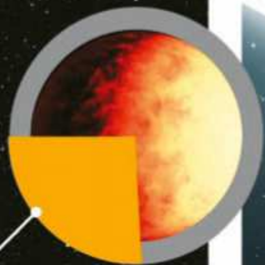

Artist's impression of the Kepler Space Telescope, superimposed over a planetary transit (not to scale)

Exoplanets in the universe

Some are much more common than others

Hot Superterrans

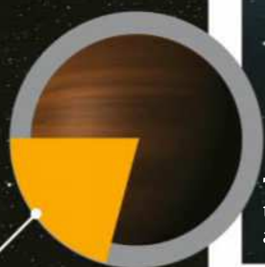
Up to 2.5-times the radius of the Earth, these planets orbit much closer to their star, and so have lost most of their early atmosphere to solar evaporation.



25.8%

Hot Neptunians

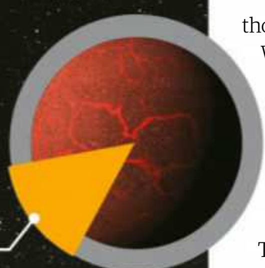
Neptunians have a rocky core, and are up to 50-times the mass of Earth, but also have a thick atmosphere of hydrogen and helium.



20.6%

Hot Terrans

Roughly the same size as Earth, but because they are in the hot zone, liquid water is not present on the exoplanet's surface.



16.0%

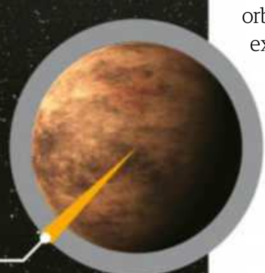
Hot Jovians

Once thought unlikely, it now seems that more than 65 per cent of Jupiter-sized planets form in their star's hot zone.

21.1%

Warm Superterrans

Planets in the habitable zone only account for about 1.4 per cent of those discovered so far, and the majority of them are larger than our home planet.



0.8%

TESS will soon extend the search for exoplanets across the entire sky

those are big, so they never moved," says Dr Kevin Walsh of the SwRI's Planetary Science Directorate in Colorado. However, computer models with these assumptions always produced a Mars that was much too big and an asteroid belt that was much too full. The only way around is to assume the gas giants are more mobile.

"That anchor point? It's gone," says Walsh. Two main competing theories have been put forward since then. The Nice model proposes that all the large planets formed much closer in and then migrated outward, triggering a bombardment of protoplanets and comets from the outer Solar System. The Grand Tack model goes further, suggesting that Jupiter first moved inward and then migrated out again.

These models go some way in explaining Mars and the asteroid belt, but they hit a major problem when we try to apply them to other planetary systems because they rely heavily on orbital resonance. This is where one planet makes exactly two orbits for every one of its neighbour, or some other neat ratio. These orbital resonances are common in our Solar System because they are energetically stable, but as soon as we look at other stars, they are nowhere to be found. "The vast majority of the Kepler planets are not in mean motion resonances," says Weiss. "Understanding why has been one of the major unsolved problems in planet formation theory over the past few years."

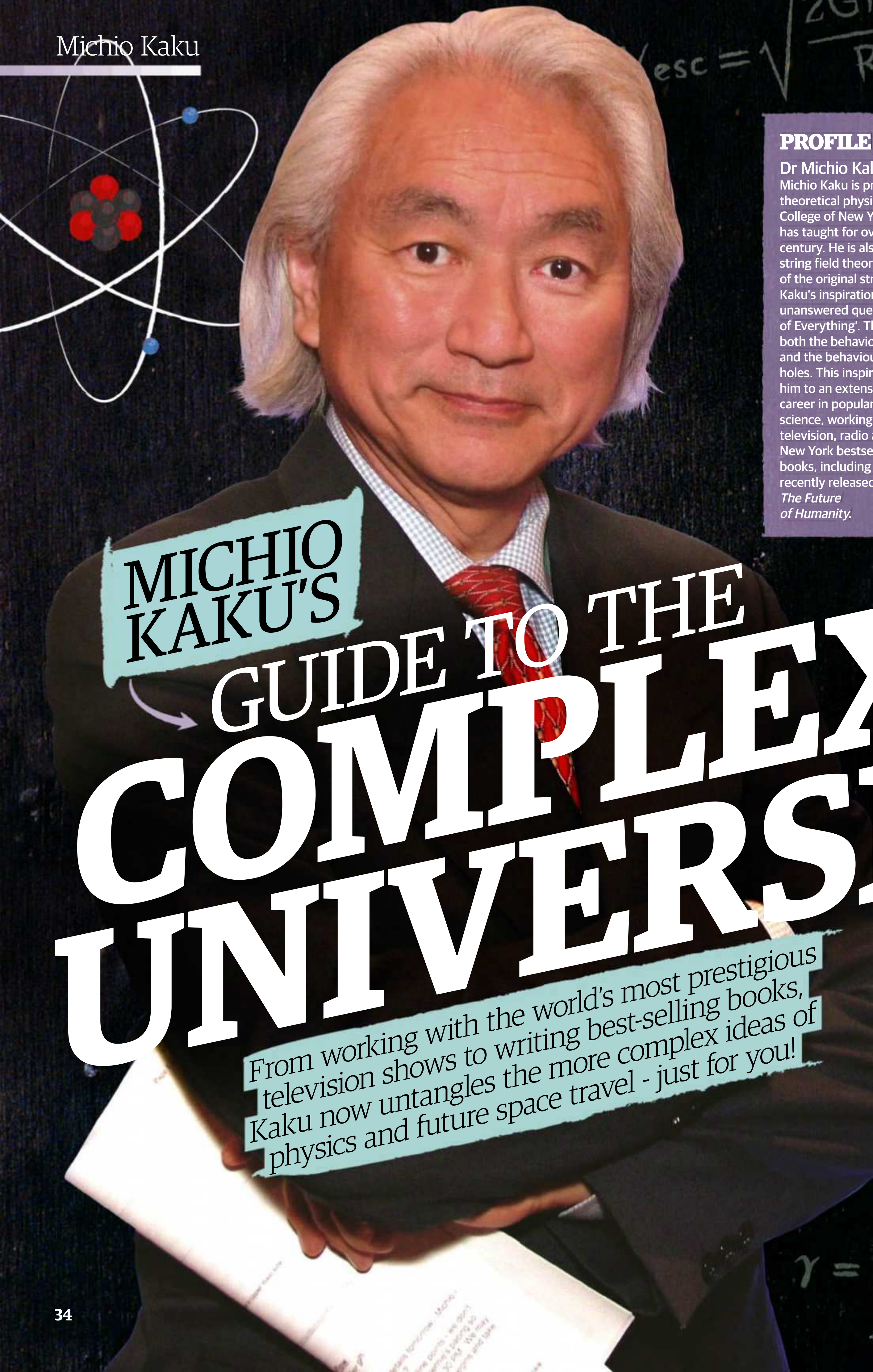
> "Jupiter and Saturn might be responsible in some not-yet-quantified way for the rise of life on Earth" **Dr Lauren Weiss**

Exoplanet orbits aren't random according to Dr Weiss. Their orbits show regular-spacing patterns that are correlated with the planets' sizes, but whatever rule they use to determine their position, it doesn't involve orbital resonance. Something about the initial conditions or the movements of our giant planets has set the stage differently. "Our Solar System is a bit of a weirdo," says Weiss.

There's a big gap between odd and unique, though, and some astronomers are not convinced we're all that special. "I would be very surprised if the Solar System were really strange," says Jack Lissauer, a planetary scientist at NASA Ames Research Center in California. "There are so many stars out there. Even if it's only one per cent, it's still not really rare."

When the Transiting Exoplanet Survey Satellite (TESS) begins its two-year survey of the entire sky this year, it will cover 400 times as much area as Kepler and look for planets around more than 200,000 stars, but even TESS won't be able to see a Earth-sized planet in an Earth orbit around a star like our Sun. Predicting how rare Earth really is will still rely on scientists fully understanding how planets form and evolve.

Mars is unusually small, which has contributed to the loss of its atmosphere



MICHIO KAKU'S GUIDE TO THE COMPLEX UNIVERSE

From working with the world's most prestigious television shows to writing best-selling books, Kaku now untangles the more complex ideas of physics and future space travel - just for you!

PROFILE

Dr Michio Kaku

Michio Kaku is professor of theoretical physics at the City College of New York, where he has taught for over a quarter of a century. He is also co-founder of string field theory, a sub-branch of the original string theory. Kaku's inspiration was Einstein's unanswered quest for the 'Theory of Everything'. This would explain both the behaviour of particles and the behaviour of black holes. This inspiration has led him to an extensive career in popularising science, working on television, radio and New York bestselling books, including his recently released *The Future of Humanity*.

There are four fundamental forces in the cosmos. Why are they important?

The universe is ruled by four fundamental forces.

We have the electromagnetic force, which lights up our cities. It's responsible for light bulbs, televisions, radio and the entire electromagnetic spectrum. Then we have gravity, which holds the Sun together, it holds the Solar System together and keeps your feet on the ground. Then we have the two nuclear forces, the weak force governs radioactive decay, and the strong force holds the protons and nucleons together.

Together they comprise all the forces known about the universe.

Weak
An incredibly small force, it causes the ejection of subatomic particles and transformation of an element. This force results in phenomena such as beta decay.

Gravity
An attractive force with the farthest reach. Gravity is what keeps the planets orbiting the Sun and keeps our feet planted firmly on the surface of the Earth.

Electromagnetism
Controls the electromagnetic spectrum, from radio waves to gamma rays. This force ensures the interactions between electric forces.

Strong
The force that keeps neutrons and protons bound together, it's considered to be the strongest among the four forces.

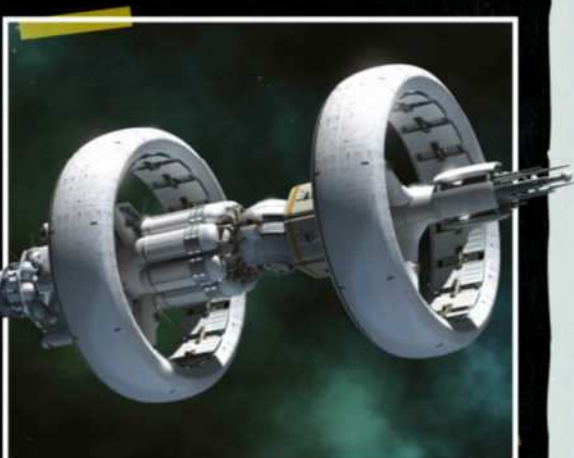
$E=mc^2$

Do you think that the warp drive will ever be possible?

Einstein said it is very difficult to break the light barrier [the speed of light]. To have a rocket go up to the speed of light you have to have fusion rockets, anti-matter rockets and maybe ramjet fusion rockets.

But to exceed the speed of light you have to invoke general relativity, and you have to have enormous amounts of energy. Energy that is comparable to an exploding star or a black hole. There is a possibility that if you can harness this vast amount of positive energy, you can open a gateway through space and time. However, you would need negative energy to stabilise it.

So if you have this rare combination of positive energy to open up the gateway, and negative energy to stabilise the gateway, then warp drive may – just may – become possible.



The Alcubierre warp drive, named after Mexican physicist Miguel Alcubierre, could allow us to harness enough energy to exceed the speed of light

What is quantum entanglement, especially in terms of teleportation?

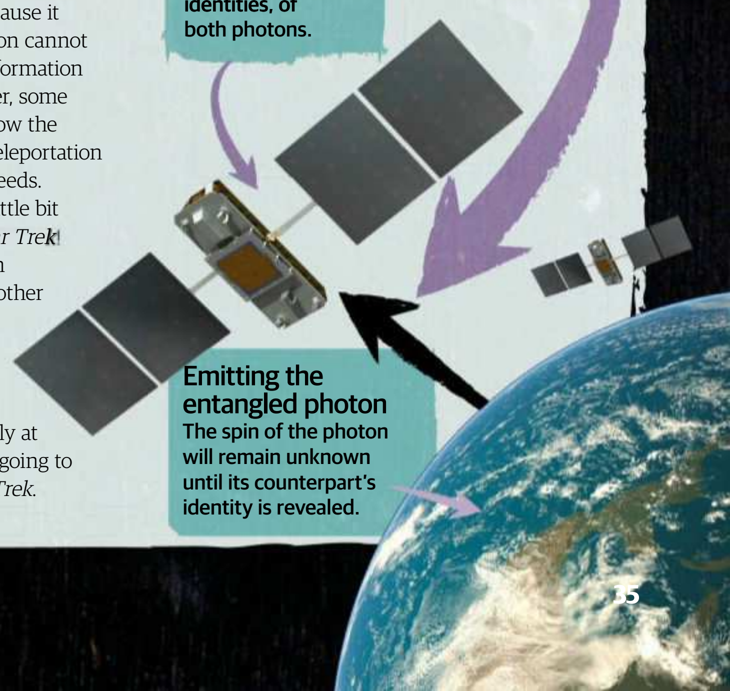
If I have two electrons arriving in unison and then separate them an invisible umbilical cord emerges, connecting the two together. So that if I jiggle one [particle], the other particle somehow senses the presence of what is happening to its twin. This sensing process goes faster than the speed of light. Einstein hated this process, and he actually used it to try and disprove quantum mechanics.

Well, Einstein was wrong. We can do this experiment in the laboratory. However, Einstein had the last laugh, because it turns out that usable information cannot be transferred this way. The information transmitted is random. However, some scientists say that if you go below the speed of light, then quantum teleportation may be possible at sub-light speeds.

Quantum teleportation is a little bit different to what you see in *Star Trek*! We're talking about information travelling from one point to another point. We've done this with atoms and photons, we can teleport particles over hundreds of feet. So quantum teleportation is possible, but only at the subatomic level. You're not going to have a transporter like in *Star Trek*.

The journey remaining unknown
The photon, travelling away from Earth, most likely to an orbiting satellite, can travel vast distances in its state of confusion.

Revealing the identity
A third photon can be introduced on the ground, interacting with one of the entangled photons. This interaction reveals the spins, and therefore the identities, of both photons.



Emitting the entangled photon
The spin of the photon will remain unknown until its counterpart's identity is revealed.

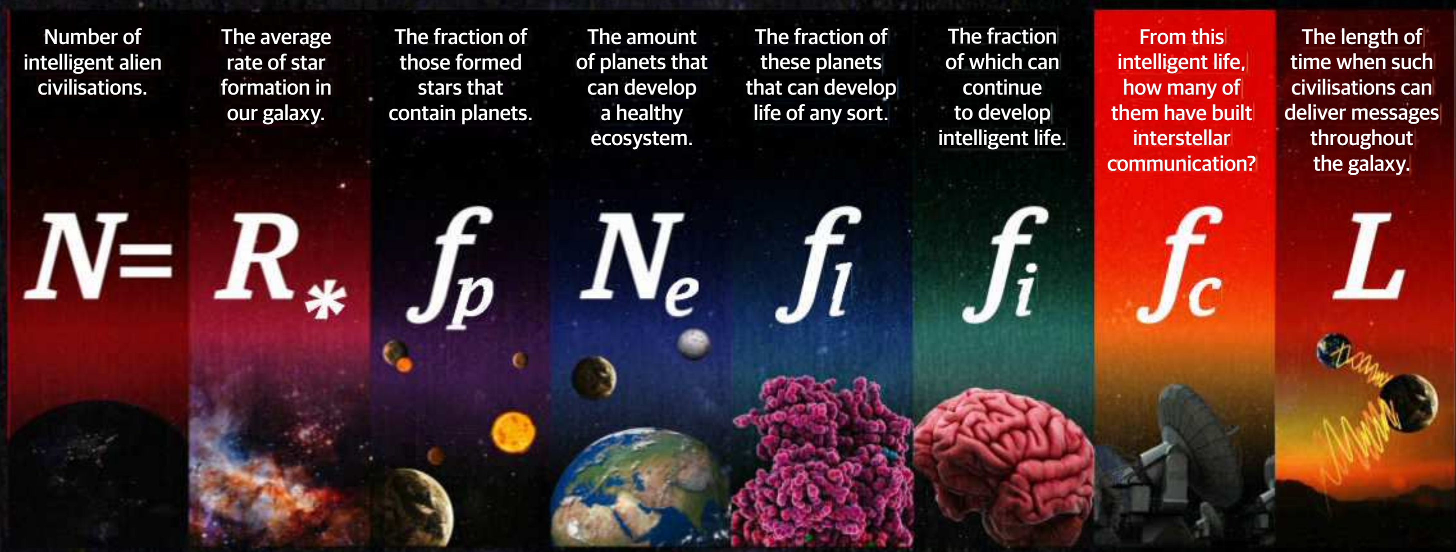
Do you think that life could exist elsewhere in the cosmos?

If you believe that the galaxy is teeming with Earth-like extrasolar planets, then you have to ask a very valid question: could there be intelligent life? In this case, why don't they visit us? Why don't they land on the White House lawn and give us the benefits of advanced technologies?

Well my attitude is this, if you're travelling in a forest and you meet the deer and the squirrels, do you talk to them? Well, yes. Initially you may want to talk to the squirrels and the deer, but eventually you lose interest because they don't talk back to you. They have nothing to offer you, so you leave them alone. I think for the most part, an advanced civilisation would view us like squirrels or deer in the forest.

Also, if you meet an anthill in the forest, do you go down to the ants and say: "I bring you trinkets. I bring you beads. I give you nuclear energy. Take me to your ant queen"? Or maybe, you have this politically incorrect urge to step on a few of them. I think that if they're that advanced that they can travel thousands of light years to reach the planet Earth, then we humans really don't have much to offer them. We're rather boring to them.

Now some people say they could be dangerous and they could be hostile. Maybe, but I don't think so. I think that if they're that advanced, they'll leave us alone. But what about plunder? They could come and plunder the Earth. Well there are a lot of planets out there with nobody on them, so you can plunder those planets much easier than plundering a planet with restive natives on it. So I think, for the most part, they'll leave us alone.



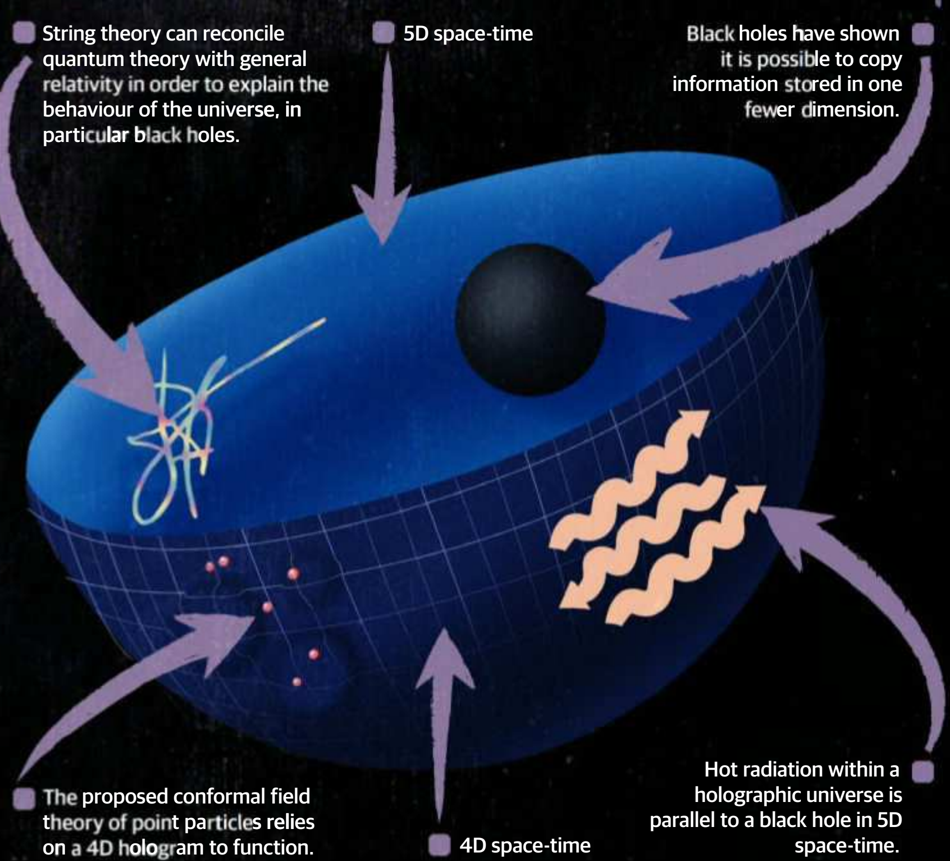
Is it possible that we're living in a simulation?

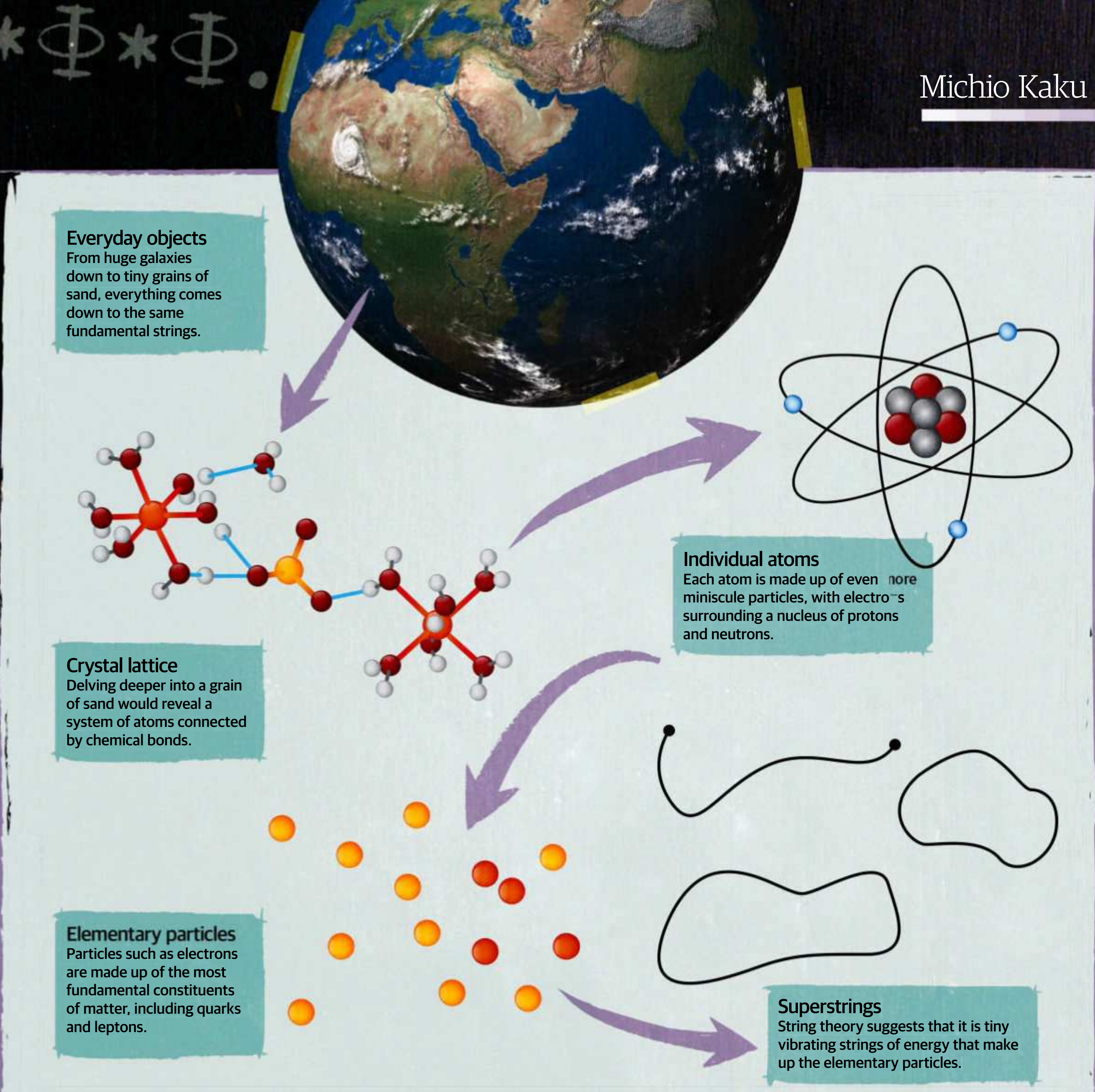
There are several interpretations of that. Some people think that reality may be a simulation, like in *The Matrix*. I don't think so.

First of all, using Newton's laws, and assuming that the atmosphere is composed of tiny little marbles instead of atoms, the world's largest computer could not simulate the atmosphere. It's too complicated. The smallest object that can simulate the weather is the weather itself. Therefore weather is 'unsimulatable', as it has too many particles.

Quantum mechanics makes it incidentally worse, because now, instead we have billiard balls representing atoms. Atoms can also spin up, spin down and spin sidewards simultaneously. So it becomes a nightmare trying to simulate quantum mechanics and the motion of particles.

Therefore I do not believe that we are in a simulation. I don't think there is a super CD-ROM where if you push the play button then here we are having this conversation. I think quantum mechanics is simply too complex, with too many possibilities, so that reality can be reduced to a CD-ROM and somebody hit our play button.





What is string theory? Why is it considered to be the theory of everything?

String theory is a single equation that allows us to summarise all the laws of the universe. Einstein spent 30 years of his life chasing after the theory of everything. He wanted an equation no more than one inch long that would allow us to "read the mind of God".

We have two great theories of the universe. We have the quantum theory, the theories that are very small, which give us lasers and atomic bombs and iPods and iPads and the Internet. That's the quantum theory, the theory of the very small. Then we have the theory of the very big. Einstein's theory of gravity and black holes and Big Bangs, but these two theories hate each other. These two theories don't like each other, so why would nature create a left hand and a right hand that don't talk to each other? That's crazy!

So we think that there is one theory that unifies the quantum theory with relativity, and that is string theory. Why do we have so many particles? We have electrons, neutrons and neutrinos. We spend billions of dollars building atom smashers to find more and more particles. [There are] 36 quarks and 19 free parameters in the standard model, and we think that all these subatomic particles are nothing but musical notes. Musical notes on a tiny vibrating string, and what is physics? Physics is harmonies, the laws of harmonies of tiny vibrating strings, that's physics. What is chemistry? Chemistry is nothing but the melodies. The melodies you can play when these strings bump into each other, creating molecules. What is the universe? The universe is a symphony, a symphony of strings, so then what is "the mind of God"? The mind of God is cosmic music resonating through 11-dimensional hyperspace.

What is matter? Why do we have planets and stars and galaxies? Why is there life and Deoxyribonucleic acid (DNA)? It's nothing but music. Music is the only paradigm rich enough to explain electrons, neutrinos, protons, DNA, stars and galaxies. It's the only paradigm rich enough to explain the universe, and that's what string theory is. String theory is considered to be the theory of everything, explaining that we are nothing but musical notes and melodies played beautifully on vibrating strings.

What is it about SpaceX's Falcon Heavy that sets it apart from other rockets we've launched beyond the Earth's atmosphere?

First of all, thousands of people lined up to watch the historic launch of the Falcon Heavy. Millions watched it online, and it was historic because this was no ordinary rocket: it was a Moon rocket, fully capable of carrying the [SpaceX] Dragon capsule around the Moon for the first time in [almost] 50 years.

We now have a Moon rocket which has been tested that can do this. Secondly, it was paid for by private funds. The United States taxpayers didn't pay one dime towards this rocket.

Thirdly, the boosters were reusable. Just like the reusable car market after World War II. A lot of the soldiers came back from war and could not afford to buy a car, because they were so expensive. The used car market opened up car ownership. It changed our culture and it can change rocket prices in the same way; they drop by a factor of ten if we have reusable booster rockets.

$260 million / £185 million

How much more a Delta IV Heavy launch costs compared to SpaceX's Falcon Heavy

Will the Falcon Heavy have a worldwide impact on space exploration?

What's new about the Falcon Heavy is that the cost of space travel is dropping dramatically. The movie *The Martian*, starring Matt Damon, cost over $100 million (£71 million). That's more than the cost of the Indian Mars rocket that reached Mars in 2014!

In other words, a Hollywood movie now costs more than a space program. So they should give Oscars to the best supporting space probe! That's how much costs have dropped.

The Chinese want to put the Chinese flag on the Moon. The Indians have already gone to Mars. We're talking about a whole new ball game with prices dropping dramatically, and that's why I think we're entering a new golden age of space travel.

7 December 1972

The last time the human race visited the Moon, as part of the Apollo 17 mission

Why is the escape velocity an important factor in launchg it?

Well, using Newton's laws of motion and gravity we can calculate that to orbit the Earth, you have to go at about 18,000 miles per hour [29,000 kilometres per hour].

To escape the gravitational field of the Earth you have to go about 25,000 miles per hour [40,000 kilometres per hour]. So every Moon rocket [in this case, the Falcon Heavy] has to have a velocity of at least 25,000 miles per hour in order to escape Earth.

25,000 miles per hour / 40,000 kilometres per hour

The speed that Falcon Heavy must go in order to escape the orbit of Earth

$35 million / £25 million

How much more *The Martian* film cost than India's Mangalyaan satellite being put in orbit around Mars

WHAT'S NEXT FOR HUBBLE?

The long-serving space telescope has been observing the universe for 28 years. What's next on its horizon could lead to even more groundbreaking discoveries

Written by Lee Cavendish

© Adrain Mann

When the Hubble Space Telescope was launched on 24 April 1990, no one thought it would last as long as it has. NASA and the European Space Agency (ESA) had collaborated to create a groundbreaking, audacious space telescope, but it didn't rise to prominence without its hiccups. Initially scheduled to launch in October 1986, the tragic loss of Challenger in January 1986, forced the agencies to postpone Hubble's launch by four years.

When the launch date finally came around, the long-awaited Hubble Space Telescope flew on board the Space Shuttle Discovery (STS-31). Discovery positioned Hubble at an altitude of 569 kilometres (353 miles) over our heads. At last the telescope was ready, and astronomers couldn't wait to feast their eyes upon the wonders of the universe it could reveal. But, unfortunately, there was another setback.


The Space Shuttle Discovery (STS-31) was launched from the Kennedy Space Center, Florida, United States on the 24 April 1990

Astronomers were hoping to view the most crisp, clear and incredible images of galaxies and nebulae. Instead, they were saddened by the return of blurry and out-of-focus images. An incorrectly installed null corrector led to a lens being out of focus by 1.3mm (0.051 inches), almost resulting in a $4.7 billion (approximately £3.4 billion) white elephant. However, with some creative thinking, corrective optics were installed on the first servicing mission in 1993, and astronomers could finally marvel at its majestic images and insightful data.

After four more servicing missions, the last in 2009, Hubble has been a picture of health. "Since the execution of Servicing Mission 4 in 2009, Hubble has been operating at its peak in terms of science productivity, and astronomers' interest remains at all-time highs now almost 28 years after its launch," explains Patrick Crouse, project manager of the Hubble Space Telescope, to **All About Space**.

The longevity of Hubble has been a pleasant surprise, with many scientists thinking Hubble would be long gone before the launch of its successor, NASA's James Webb Space Telescope (JWST), due to be launched in the spring of 2019. Now it looks more likely that the space telescopes' lifetimes will overlap, giving scientists and researchers a few years to utilise having two of the greatest telescopes in space at the same time to gather precious information about the universe.

There is something Hubble can do that the JWST will not have the capabilities for though, and that's observing ultraviolet light. JWST will be able to observe visible to mid-infrared light in unprecedented detail, but not ultraviolet. This is why the Hubble scientists are urging researchers to gather as much ultraviolet information as they can with Hubble before it's too late. Once Hubble is decommissioned, these precise measurements of celestial objects in a wavelength unperceived by the human eye will no longer be available.

"We're encouraging them [researchers around the world] to consider making ultraviolet light observation proposals in order to give us information and data for future use. This will be more scientifically valuable because the Hubble Space Telescope can see in ultraviolet light, but there's no space telescope [planned to launch] in the near future that will be able to make these observations, and we cannot receive ultraviolet light from the ground because the atmosphere blocks it," Dr Jennifer Wiseman, senior project scientist for the Hubble Space Telescope, explains. "Hubble is unique in this capability of doing ultraviolet light observations and it is very informative for all kinds of astronomy. We use it both for studying the Solar System as well as studying the intergalactic medium – the material that connects galaxies. Those are just two examples of features in space that ultraviolet observations can truly illuminate and help us understand."

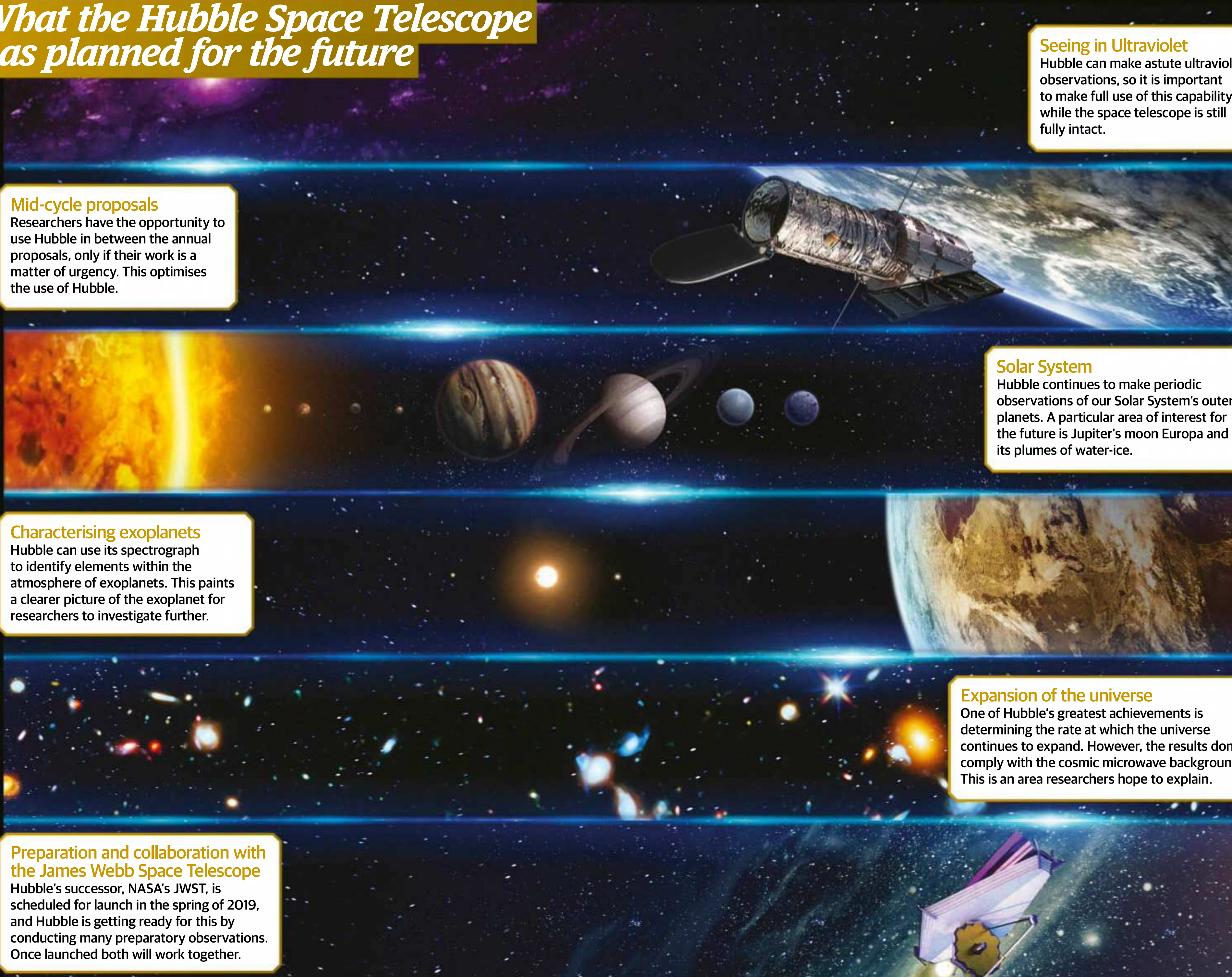
Ultraviolet can tell us a lot of hidden information about the universe, particularly about the birth of hot, young stars. The intergalactic medium contains copious amounts of gas and dust, material fundamental for bringing life to stars. Ultraviolet spectroscopy – the splitting apart of light to observe chemical signatures – can tell us what elements are in these gas clouds, what temperature it is and even their density. From this, we can deduce what the ideal conditions are for stars to be born.


Dr Jennifer Wiseman is the senior project scientist for the Hubble Space Telescope

"Hubble is unique in this capability of doing ultraviolet light observations. It is very informative" **Dr Jennifer Wiseman**


Hubble's final servicing mission occurred between 11-24 May 2009

What the Hubble Space Telescope has planned for the future



Seeing in Ultraviolet
Hubble can make astute ultraviolet observations, so it is important to make full use of this capability while the space telescope is still fully intact.

Mid-cycle proposals
Researchers have the opportunity to use Hubble in between the annual proposals, only if their work is a matter of urgency. This optimises the use of Hubble.

Solar System
Hubble continues to make periodic observations of our Solar System's outer planets. A particular area of interest for the future is Jupiter's moon Europa and its plumes of water-ice.

Characterising exoplanets
Hubble can use its spectrograph to identify elements within the atmosphere of exoplanets. This paints a clearer picture of the exoplanet for researchers to investigate further.

Expansion of the universe
One of Hubble's greatest achievements is determining the rate at which the universe continues to expand. However, the results don't comply with the cosmic microwave background. This is an area researchers hope to explain.

Preparation and collaboration with the James Webb Space Telescope
Hubble's successor, NASA's JWST, is scheduled for launch in the spring of 2019, and Hubble is getting ready for this by conducting many preparatory observations. Once launched both will work together.

As making use of a telescope living on borrowed time is of the highest priority, Hubble scientists have introduced a 'mid-cycle proposal initiative'. "This is a special additional opportunity that astronomers have at two other times in the year, so we call them 'mid-cycle proposals', with a cycle being a year basically," says Wiseman. "These extra opportunities allow astronomers to make the case that if they go ahead and make a short observation with Hubble that's a time-sensitive issue, it will help them to have a richer proposal when the regular annual cycle proposal comes around."

By allowing astronomers to fast track the usual annual proposal process, assuming that their mid-cycle proposal fits the urgent protocol, the efficiency for the 28-year-old space telescope can be optimised while it is still in fantastic condition. Even if this work never goes further than that, the observations will always remain in the fine collection of datasets that is the Hubble archives. Already the Hubble archive is making tremendous contributions to science with new discoveries; about half of the published scientific papers based on Hubble data have come from this trove of forgotten gems.


Patrick Crouse has been Hubble's project Manager for eight years

"There is another area we are using Hubble in which I think is of prime importance, and that is studying our Solar System," explains Wiseman. Although Hubble spends a lot of time staring into deep space, pondering upon the darkest, deepest galaxies in the universe, it can also tell us much about the outer planets in our Solar System. The only instruments that can produce clearer pictures are the ones that have flown past the planets, such as Juno, Cassini, the Voyager spacecrafts and so on. The advantage that Hubble has over these exploration spacecrafts, however, is that Hubble can observe these planets periodically for many years.

With this perpetual 'checking in' on our outer planets, Hubble managed to capture the spectacular collision between comet Shoemaker-Levy 9 and Jupiter in July 1994. Hubble has also deduced that the aforementioned planet's Great Red Spot (GRS), a storm about 1.3-times the diameter of Earth, is shrinking. Even today scientists continue to make new discoveries thanks to these periodic observations. For instance, scientists recently caught a storm – originally long enough to stretch from the East Coast of the United States to Portugal – on the face of Neptune shrinking before its very lens.

As for the future, scientists are extremely keen to keep a close eye on Jupiter's moon, Europa. Europa has exhibited plumes of water escaping from within the moon, meaning that there could be a subsurface ocean. With Hubble's ultraviolet capabilities a lot can be learned from the water beneath the ice, and it could even point out the existence of microbial life.

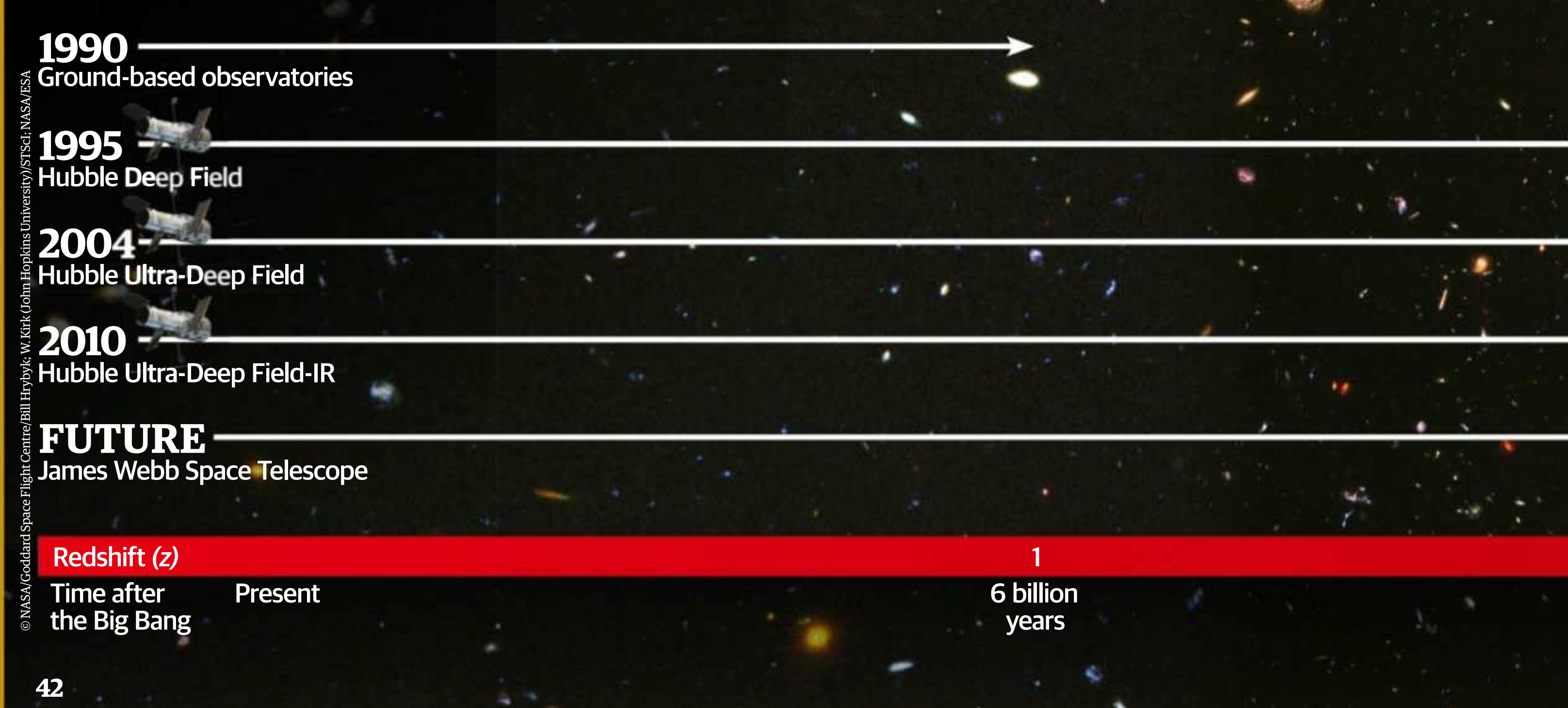
Even beyond our Solar System we are still learning about planets in our galaxy, the Milky Way. More specifically the atmospheres of exoplanets – planets orbiting a star other than our Sun. "Hubble is very useful for studying the atmospheric compositions of some of these exoplanets, so we're using Hubble very intensively to do that on as many exoplanets as we can," explains Wiseman. "We've already found water vapour in the atmospheres of several exoplanets, and we're continuing to characterise as many as we can in several wavelengths of light."

Moving beyond the Milky Way, the Hubble Space Telescope has played a vital role in understanding the expansion of the universe or, more appropriately, causing even more confusion surrounding the expansion of the universe. Dr Adam Riess, 2011 Nobel Prize laureate and astrophysicist at the Space Telescope Science Institute and Johns Hopkins University, both in Baltimore, Maryland, United States, formulated an innovative technique that led to a more accurate figure for the Hubble constant.

The Hubble constant is the rate at which the universe is expanding, and after eight long years of observing Cepheid stars, Riess and his team were able to conclude that the universe is expanding five to nine per cent faster than expected. When the refined Hubble data is compared with information we can see from the cosmic microwave background

How Hubble will benefit the James Webb Space Telescope

When NASA's James Webb Space Telescope receives first light it will be ready to peer earlier into the universe's history than ever before. Until then, Hubble can identify and analyse the earliest galaxies its optics allow, singling out targets for the JWST to look at once its time has come.



Adam Riess won the Nobel Prize in Physics in 2011 for his research on the expansion of the universe

(ancient radiation left from the Big Bang), astronomers can't get the two results to match up, which means there could be something wrong with our understanding. Riess says that this can be thought of as building a bridge, with the Hubble findings on one side and the cosmic microwave background data on the other. "You start at two ends, and you expect to meet in the middle if all of your drawings are right and your measurements are right. But now the ends are not quite meeting in the middle, and we want to know why."

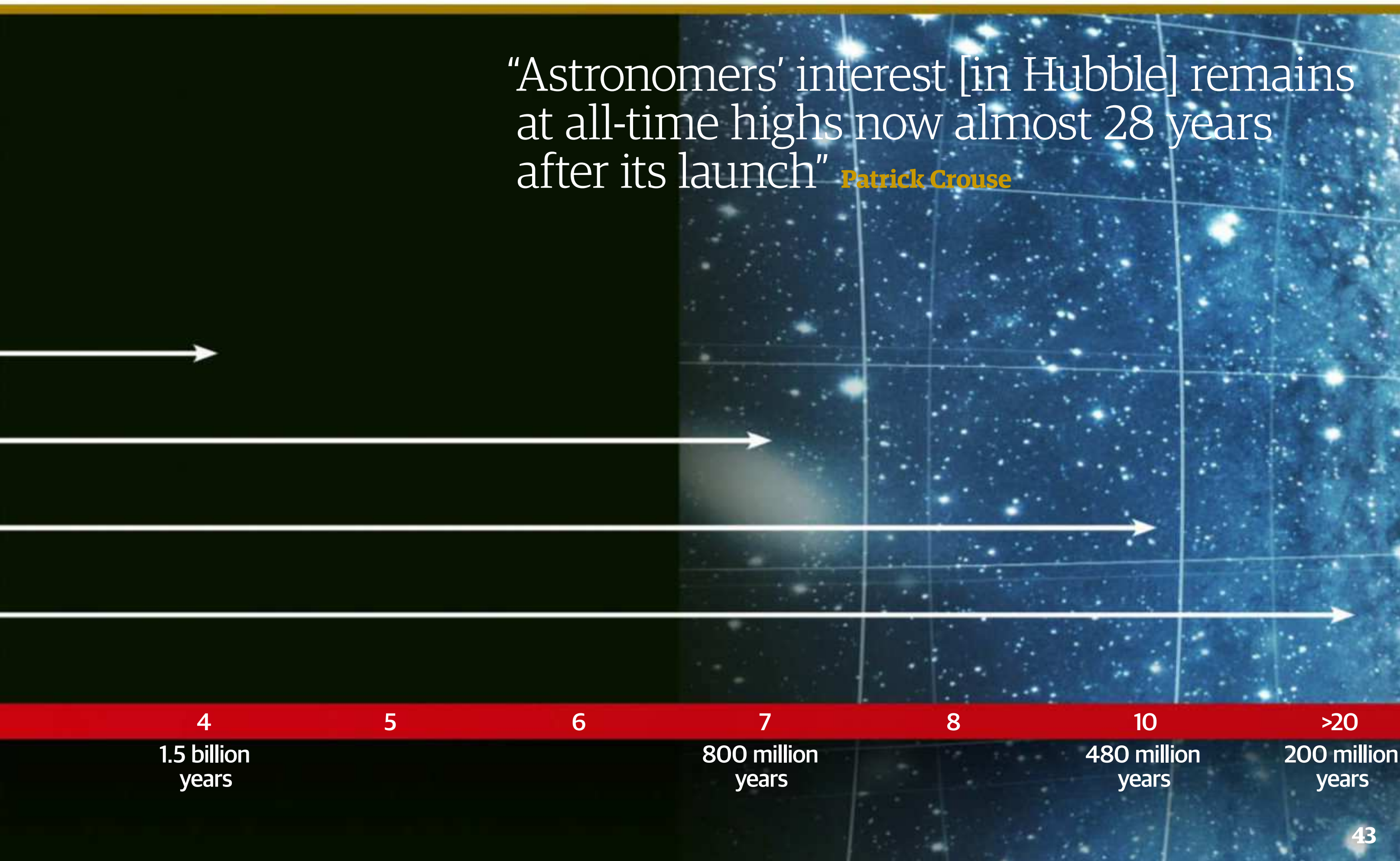
This incentive continues to drive astronomers in their quest to understand the elusive dark energy theorised to be fuelling the expansion of our universe. Since 2005, the uncertainty for the Hubble constant value has been reduced to just 2.4 per cent, which is a 76 per cent reduction. However, Riess and his team strive to make this uncertainty just one per cent, and hopefully connect the bridge between the two sets of data.

In spite of all that, it has become abundantly clear that the hard-working Hubble team at NASA are planning heavily for the arrival of the agency's highly anticipated James Webb Space Telescope. Prior to its arrival, Hubble will spend a fair amount of its time in the coming years undergoing preparatory observations and getting all the aims, objectives and targets ready for when the new space telescope receives first light.

"We look forward to overlapping operations with the JWST telescope and the resulting

On Hubble's 25th anniversary, it celebrated by snapping this marvellous shot of the star cluster Westerlund 2

"Astronomers' interest [in Hubble] remains at all-time highs now almost 28 years after its launch" Patrick Crouse



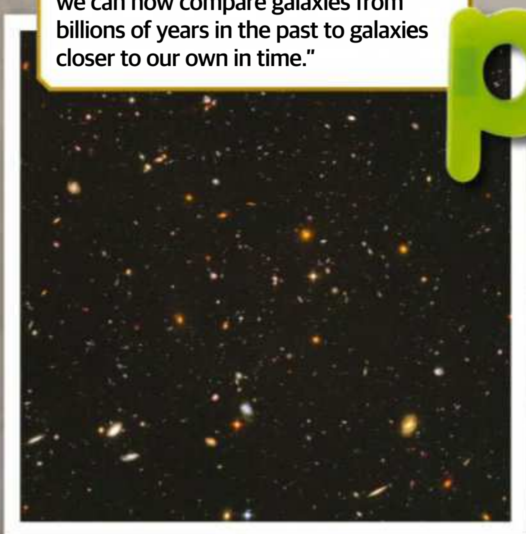
The Hubble team pick their favourites

The scientists behind the mission reveal some of their favourite images and explain what they mean for understanding of the universe

Hubble's Ultra-Deep Field

Dr Jennifer Wiseman, senior project scientist

"The image is mind-blowing when you realise that this tiny area of the sky contains thousands of galaxies. These galaxies showed up when Hubble collected light over several days, revealing even very faint objects. What is incredible to me is that astronomers have analysed many of these galaxies and determined their distances so that we can now compare galaxies from billions of years in the past to galaxies closer to our own in time."



M104, Sombrero Galaxy

Kevin Hartnett, science operations manager

"I chose this one because of its majestic expanse, exquisite details along its dusty disc, glowing stellar halo, numerous globular clusters, and the tiny background galaxies visible in the image. I've seen M104 with my own backyard telescope, so this makes it all the more interesting."

Galaxy cluster SDSS J1038+4849

Dr Knicole Colón, deputy operations project scientist

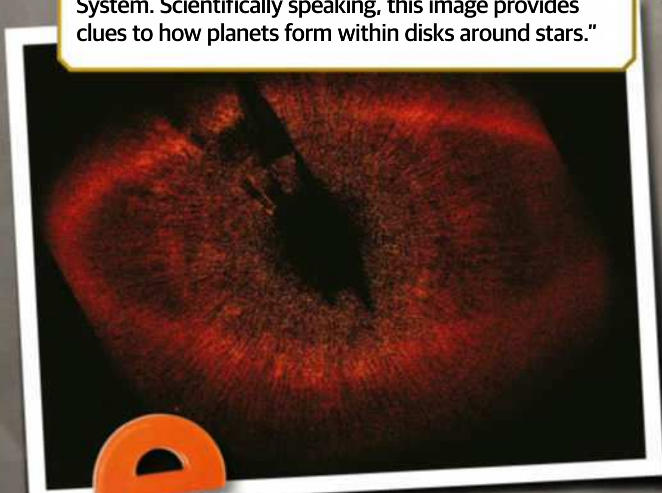
"What I like about this image is that it simply makes me happy when I look at it. When you see someone smile at you you're more than likely going to give a smile in return.

"To me, this is nature's way of showing us the beauty in the universe in a way that we as humans can relate. What this image shows scientifically speaking is a cluster of galaxies and the effects of gravitational lensing."

Fomalhaut System

Dr Knicole Colón, deputy operations project scientist

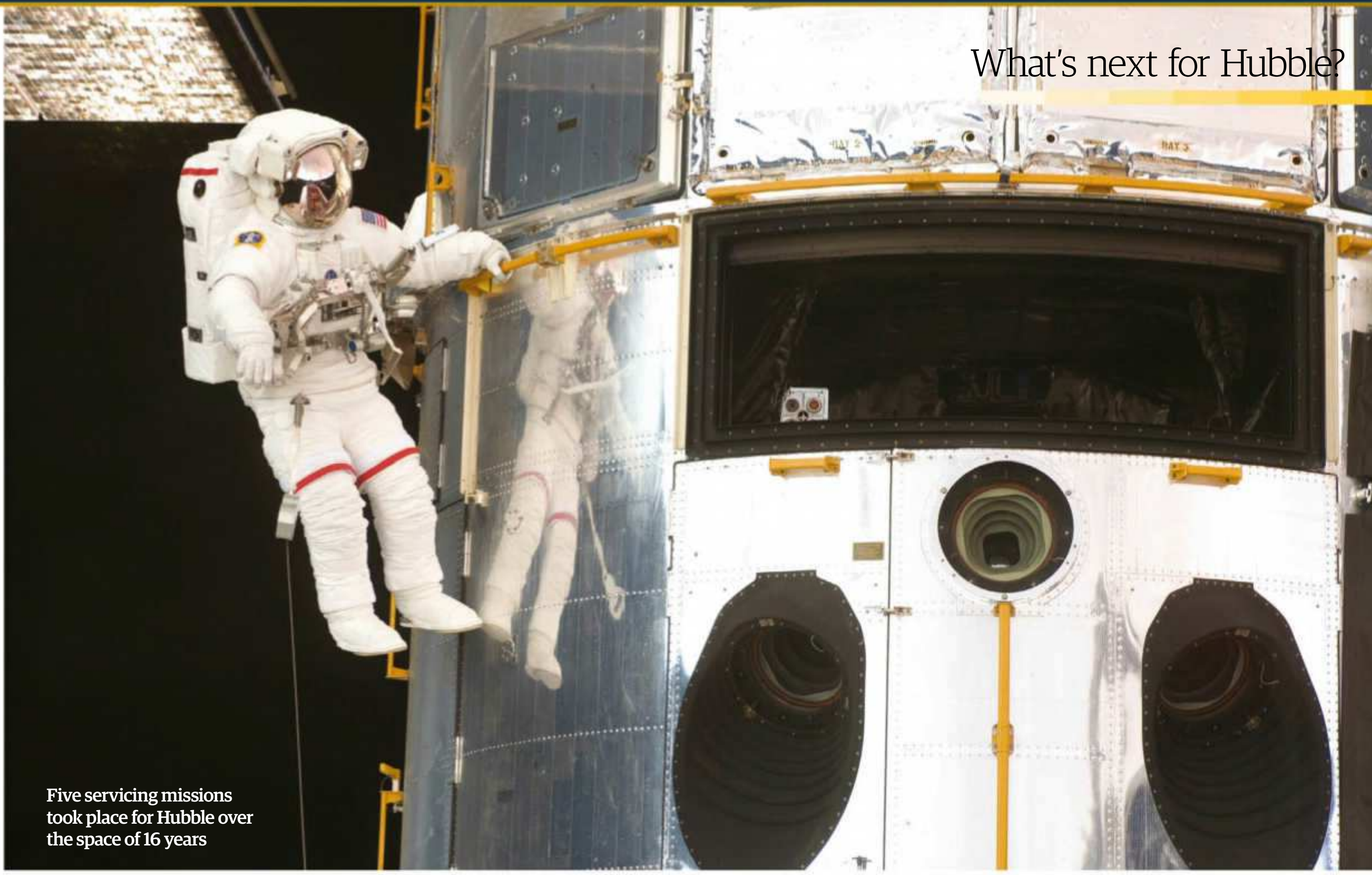
"The first time I saw this image my jaw might have literally dropped. I thought it was both beautiful and inspirational that we now live in a time when we can take 'direct' pictures of planetary-size objects orbiting other stars located tens of light years from our Solar System. Scientifically speaking, this image provides clues to how planets form within disks around stars."



M16, the Eagle Nebula

Kevin Hartnett, science operations manager

"I chose the famous 'Pillars of Creation' images, especially the more recent version showing both the UVIS and IR versions [both are channels attached to Hubble's Wide Field Camera 3], for its stunning beauty and its impact on our understanding of star-birth environments."



Five servicing missions took place for Hubble over the space of 16 years

"We look forward to similar, joint programmes with JWST so that investigators can coordinate the study of celestial objects in detail" Kevin Hartnett

complementary science opportunities, which we expect to be very exciting," says Crouse.

Kevin Hartnett, science operations manager of the Hubble Space Telescope tells **All About Space**: "Once James Webb Space Telescope is launched and is taking science we look forward to similar, joint programmes with JWST so that investigators can coordinate the study of celestial objects in detail panchromatically, that is, across the electromagnetic spectrum, from ultraviolet to infrared wavelengths."

The JWST will be able to do the same things as Hubble Space Telescope – minus ultraviolet observations – but better. With its 18 hexagonal mirrors, each beryllium blank is coated in gold, congregating into a 6.5-metre (21-foot) primary mirror, it will tower over Hubble's 2.4-metre (7.9-foot) mirror, allowing for marvellous light-capturing capabilities. With this incredibly powerful instrument at NASA's disposal, astronomers are now planning what the first targets will be in order to kick-start a new era of deep-space exploration.

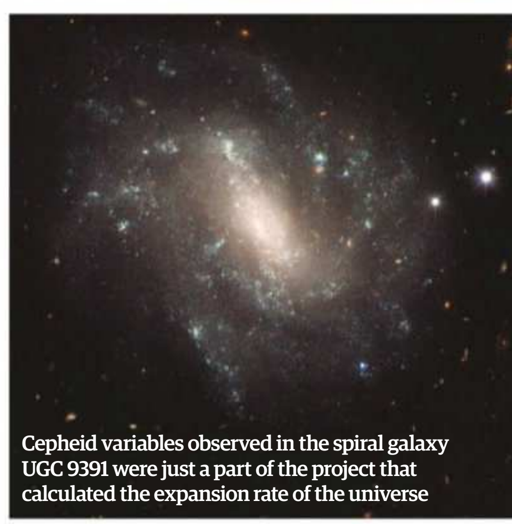
One area that astronomers around the world are at the edge of their seats for, in terms of JWST's preliminary results, are observations with respect to the most distant galaxies in the universe. The most distant galaxies are normally referred to as high-redshift galaxies. This is because the more distant the light source is, the more stretched the light's wavelength is towards the red part of the spectrum.

But what can these distant galaxies tell us about our universe? The answer is that they can tell us about the early ages of the universe, due to the limited speed of light and the large distance travelled since the birth of these galaxies.

In March 2016, Hubble imaged the most distant galaxy in the universe. It was dubbed GN-z11, based on the fact it has a redshift value (z) of 11. As light is limited to the speed of 300,000,000 metres per second (671,000,000 miles per hour), the light from GN-z11 had taken over 13 billion years to reach us. Hubble had just spotted a galaxy that formed just 400 million years after the Big Bang! With the greater light-gathering capabilities of JWST, we could potentially unlock a whole new horde of remote, young galaxies. This information can then tell us what the universe was like just a few hundreds of millions of years after the Big Bang.

Even after 28 years of around-the-clock operation, Hubble remains the most successful and scientifically significant telescope ever created. It is remarkable what it has done, what it is currently doing and what it will do in the future. However, with its longevity in question and the eventual arrival of the JWST, it's clearly important to utilise these precious final years. After all, Hubble has built, and will continue to build, an amazing collection of data for scientists all over the world to prosper from long after the telescope itself has gone.

Hubble's unique ultraviolet capabilities emphasise the intense star formation occurring in a galaxy



Cepheid variables observed in the spiral galaxy UGC 9391 were just a part of the project that calculated the expansion rate of the universe

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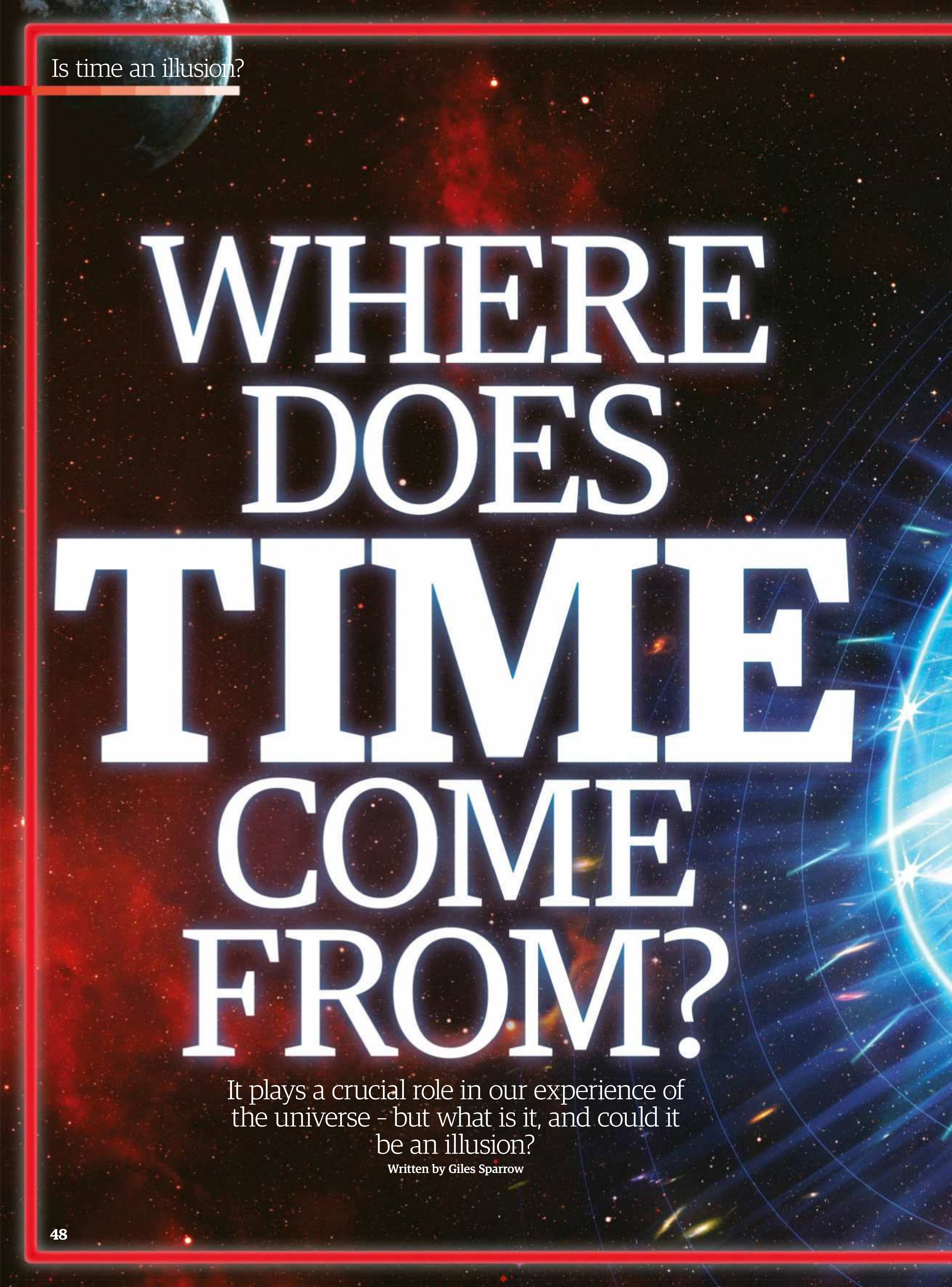
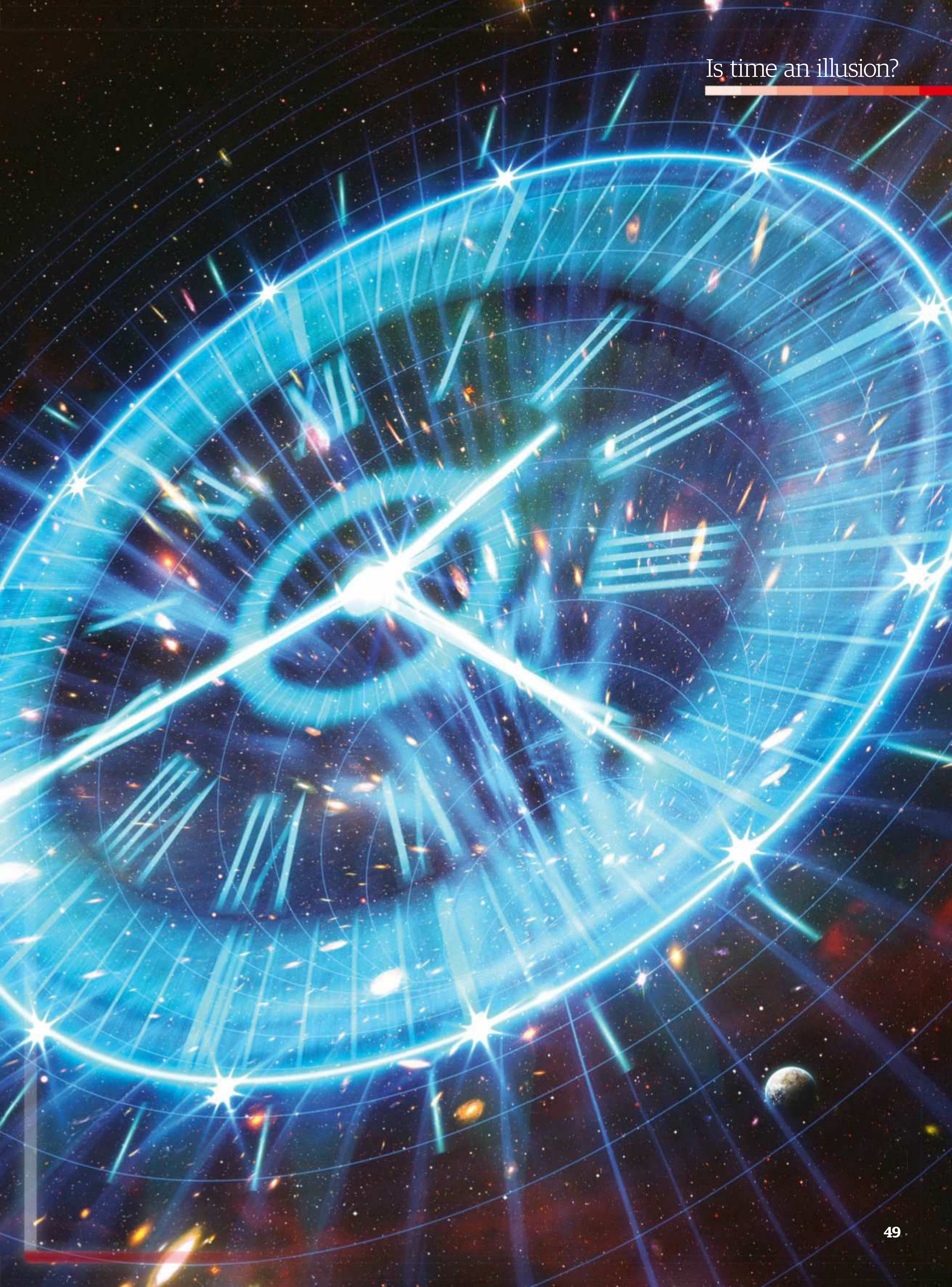


WHERE DOES TIME COME FROM?

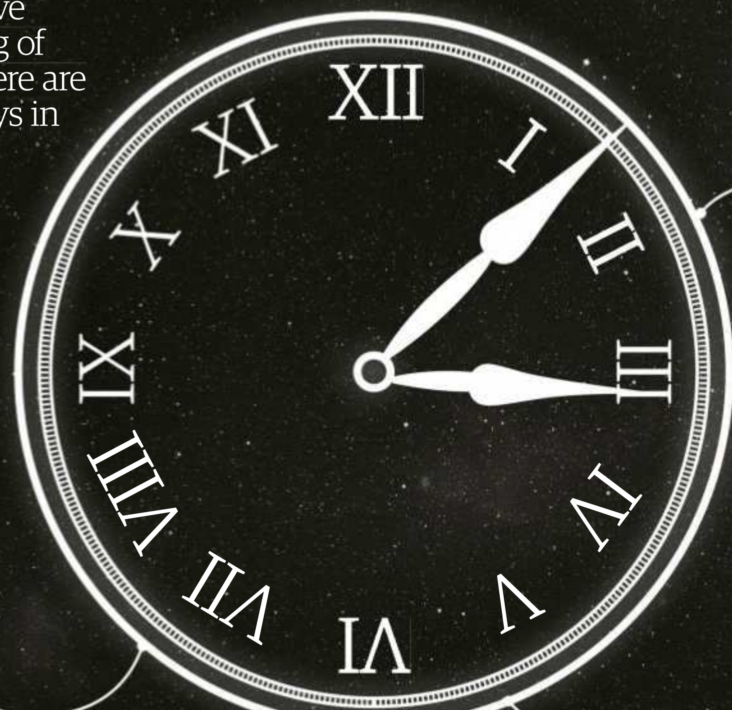
It plays a crucial role in our experience of the universe – but what is it, and could it be an illusion?

Written by Giles Sparrow



What don't we get about time?

Cosmologists think they have a pretty good understanding of time as a dimension, but there are still questions about the ways in which we experience time



Do we really have free will?
Do we really have the ability to make unfettered choices about future events, or are we simply following a predetermined course without being aware of it?

Why can't we move back in time?
In theory, general relativity permits movement along 'closed timeline curves' that could take a person back in time. But why is it that, in practice, the equations never seem to work out?

Why don't we remember the future?
Some physicists think that our ability to form memories is linked to an increase of entropy in our brains, but there's still no comprehensive theory for how this could work.

Time is a constant part of our everyday lives – even as you read this sentence, its first words have disappeared into the past while the next paragraph looms up from the future. We're so used to the experience of flowing time that we very rarely stop to think about what it really is or why it works in the way that it does.

While most cosmologists agree that time is an innate feature of the universe with its direction defined only by other laws of physics, a controversial new theory suggests that its flow could be driven by the fact that our universe is expanding – an idea which means that, at least in theory, time could one day be thrown into reverse.

Fortunately, even though time is hard to visualise, scientists have a well-established way of treating it as a fourth dimension: a direction in which phenomena can change their location, similar to the familiar three dimensions that locate objects in space.

"Time is not that hard to understand," says Professor Sean Carroll, research professor at the California Institute of Technology and author of *From Eternity to Here: The Quest for the Ultimate Theory of Time*, optimistically. "I don't think it's a mystery, and I don't think it's been a mystery for a very long time. It was a bit simpler back when we had Isaac Newton and time and space were both absolute. Then we would have considered the universe to be made of space and everything in it, and the universe keeps happening over and over again – time is just the label we put on those different versions that happen one after another with things in different positions, a bit like the pages of a book."

As he explains, our modern view of time – superseding Newton's – was shaped by the breakthroughs of Albert Einstein a little over a century ago: "In Einstein's view there's actually 'space-time' [a structure with four dimensions that determines how objects are located in the universe], and how an observer slices that space-time into time and space is a little arbitrary – different people can look at it in different ways, and no one is right and no one is wrong. But still, in any one point of view there's a sequence of moments. It's a little more complicated, but really it's not that hard – it's certainly no more profound to ask what time is, than-to-ask-than, what space is.

"I guess I'm smuggling in an eternalist point of view here, which treats every moment of time as on an equal footing, as opposed to a 'presentist' point of view that says only the world right now is real. In a post-Einstein world that's really not how many physicists think," he continues.

> "It's that riding the wave of the increasing entropy of the universe that gives us the perception of the flow of time" **Prof Sean Carroll**

General relativity allows flexibility in space-time, perhaps including the possibility of 'wormhole' tunnels between one region of space-time and another

But if every moment in time is equivalent, why can't we move back and forth in time at will – why does time only appear to flow in one direction, and does it really 'flow' at all?

"An important subtlety is the difference between time as a label on different points versus the 'arrow of time' – the fact that the past and future are different for us in a way that is not true for space," explains Carroll. "All directions in space are the same (at least outside the influence of gravity), but in time the two directions are very different, and there's just one direction that we go in."

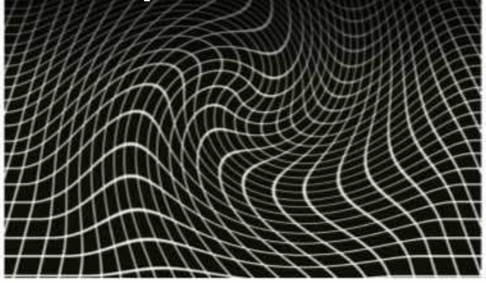
Ask most physicists about the arrow of time and they'll almost certainly explain it in terms of the second law of thermodynamics (the science that relates heat and energy, discovered and expanded upon during the 19th century). The second law is a simple statement that says the amount of disorder or 'entropy' in a closed system increases with time, unless energy is supplied to create more order.

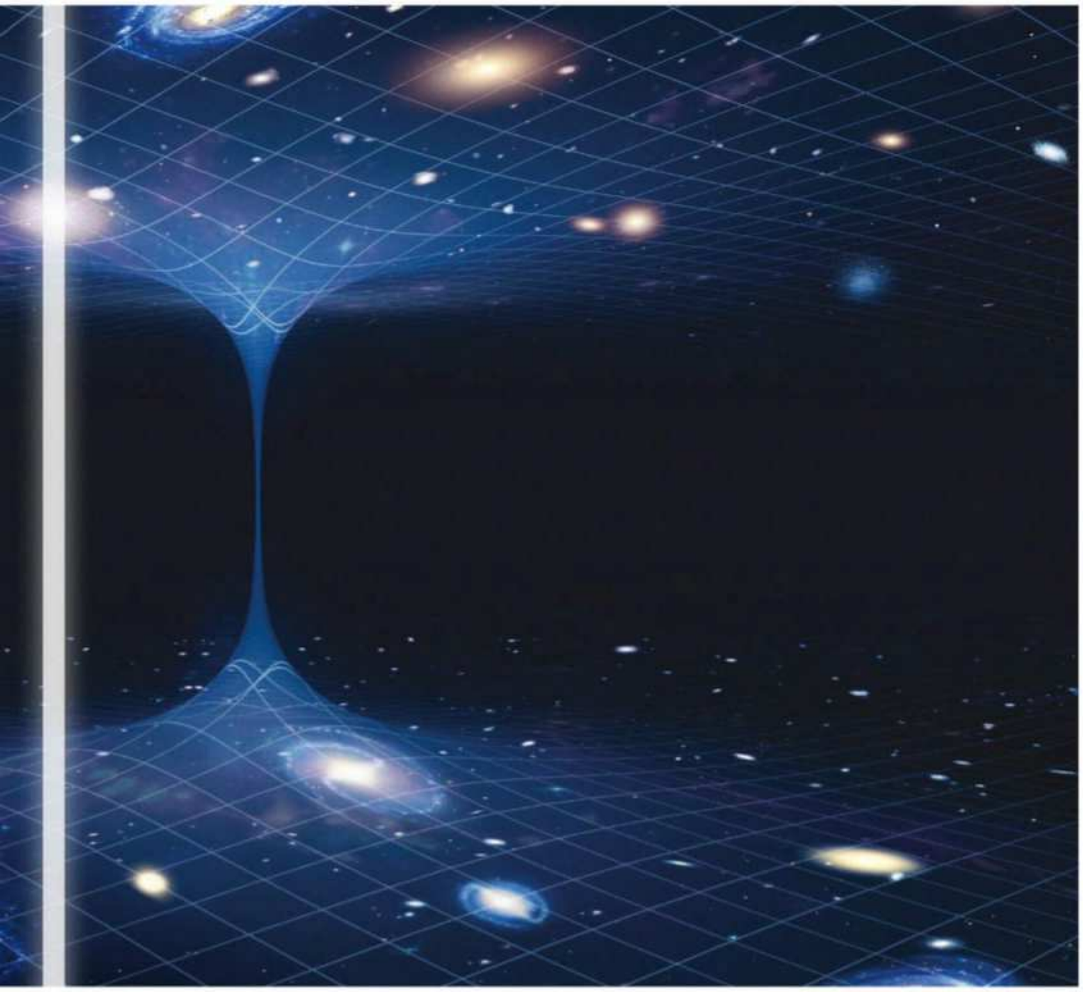
The system can be anything, and its entropy can be thought of as the 'useless' energy within it. A classic example is a pair of boxes containing hot and cold gases with a connecting door between them. At first this particular arrangement's entropy is low because most of its energy is in useful form – locked up in hot, fast-moving gas molecules in one box that could be used, for example, to pump an engine piston.

Open the door between the boxes, however, and over time the gas molecules of different temperature will inevitably mix together. Hotter gas molecules will collide with colder and slower-moving ones, transferring energy until eventually both boxes are filled with gas of an intermediate temperature. A once-orderly system with low entropy has now become a disorderly (high-entropy) system of jumbled molecules with less capacity to do useful work.

But what exactly does all this have to do with the direction of time? Well, according to current cosmology, the universe too can be thought of as a closed system – there's only so much energy to go around and no way of supplying energy from outside to reverse the rise of entropy. The universe therefore started out in a highly ordered, low-entropy state (the Big Bang era where all matter had uniformly high temperatures), and entropy

In 1908, Hermann Minkowski showed how space and time could be modelled as a four-dimensional space-time 'manifold'





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Time's evolution

c. 3000 BCE
Keeping track of the seasons
Most living things on Earth have some conscious or unconscious 'time sense' in the form of adaptations to the seasonal cycles as Earth moves around the Sun.

c. 2000 BCE
Water clocks
The first devices used to keep track of shorter periods were water clocks. These estimated the passage of time through the accumulation of steady drips of water.

c. 1500 BCE
Sundials
First used in ancient Egypt, sundials keep time by tracking the path of the Sun's shadow. Differences in its path throughout the year make them inaccurate, though.

c. 3000 BCE – 1200 CE
Mechanical timekeepers
Sophisticated water clocks began to use escapement mechanisms that harnessed the power of falling water and released it in small regulated movements.

1656
The first pendulum clock
Dutch scientist Christiaan Huygens saw that a pendulum of a fixed length always swings with the same period, regardless of the arc of its swing. Using weights and an escapement to keep it moving, he developed a more accurate timekeeper.

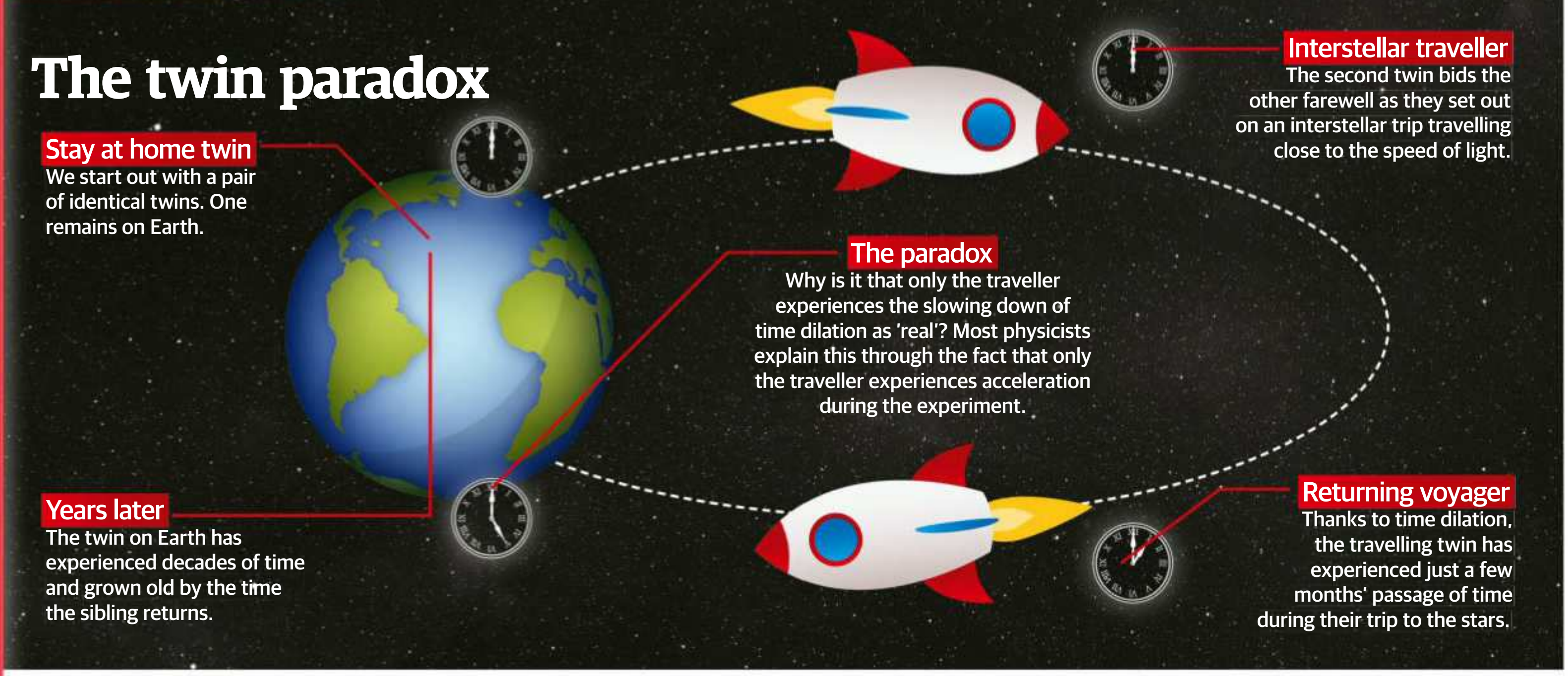
17th-18th century
The longitude problem
If sailors knew the time at home port they could work out their position on Earth from observations. Finding a timekeeper that worked at sea proved a struggle.

1735-61
The marine chronometer
Yorkshire clockmaker John Harrison built a series of increasingly accurate timepieces that could be used at sea, solving the longitude problem.

1927
Quartz vibrations
In 1927, engineers at Bell Laboratories in the US worked out how to use quartz crystals to generate extremely regular vibrations that could drive a clock.

1955
Atomic clocks
Louis Essen and Jack Parry of the UK's National Physical Laboratory built the first accurate atomic clock. They are used as the ultimate scientific timekeepers.

The twin paradox



has been increasing ever since. Today, much of its matter is still concentrated in low-entropy systems such as stars, but in the far future, as succeeding generations of stars burn out, the cosmos will succumb to 'heat death' in which matter and energy become more and more evenly and thinly spread.

"In my perspective, the arrow of time just comes from the fact that the entropy of the universe was smaller in earlier times and grows larger at later times. There's nothing propelling the universe forward in time, it's just you have all these different moments distinguished by the rule that earlier means lower entropy, later means higher entropy,' says Carroll. "That explains why you can remember the past and not the future, why you can make choices about the future but not the past and so forth. There are good reasons why a person, considered as a series of people at moments in time with increasing entropy, feels that time flows in that direction.

"It's more of a psychological effect than anything else – we carry around in our minds a moving image of what we were a second ago, what we will be a second from now, and we're constantly updating on the basis of what we learn, how our surroundings change and so on. It's that riding the wave of the increasing entropy of the universe that gives us the perception of the flow of time. If, however, the idea is that there's some active element of reality that pushes the universe forward in time to bring about change, then that's not really part of physics as we understand it."

Nevertheless, that possibility of a 'driving force' behind the flow of time is where a controversial new idea put forward by physicist Richard Muller of the University of California, Berkeley could come into play. Muller's own 2016 book, *Now: The Physics of Time*, suggests that time is a real phenomenon, and that more time is created as space itself grows.

While Carroll and many other cosmologists are doubtful about the need for a driving force behind the arrow of time, Muller does at least put forward a plausible way of testing his proposal. The idea comes from gravitational waves – the minute distortions of space-time that ripple out across the universe from certain cataclysmic events involving large asymmetric masses.

Although such waves were predicted by Einstein in the early 20th century, they have only been detected at the super-sensitive Laser Interferometer Gravitational-Wave Observatory (LIGO) in the past couple of years. Muller and his Caltech collaborator Shaun Maguire argue that because the black hole collisions that generate gravitational waves create 'new' space, they should also create a small amount of new time. What's more, the quantities of time involved (around a millisecond) are large enough to be measurable using existing LIGO instruments, so Muller's intriguing hypothesis could either be proved wrong or pass its first observational test in the relatively near future.

While Muller's model of time is a radical departure from those supported by the majority of cosmologists, the way it makes the flow of time 'real', rather than something merely defined by the increase of entropy, gives it an obvious intuitive appeal. Technically, the difference between the roles of time and those of other dimensions is its lack of 'symmetry'. Physicists define symmetry as the property of a system that remains unaltered by a 'transformation' or movement in terms of one or more dimension. A system can be transformed

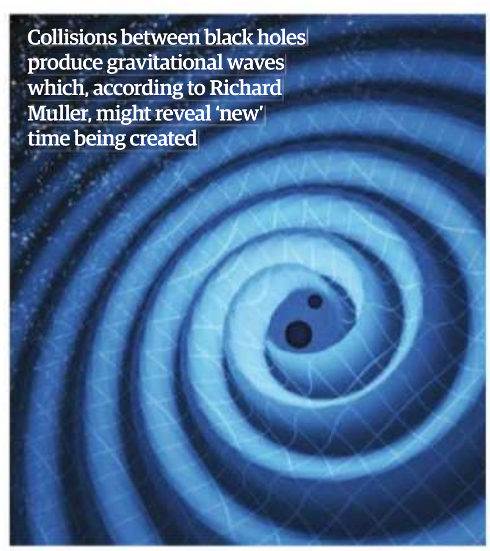
The arrow of time

Another way of looking at the arrow of time is through the lens of possibilities – when we say that 'entropy increases', we mean that things have a wider variety of possible states in the future than they do in the past

An orderly egg
An unbroken egg can be unbroken and perfect in just one way – so we can say that it has relatively low entropy.

Network of cracks
If we crack the egg, its shell can break in different ways – the cracked egg has higher entropy than the whole one.

Smashed to bits
Dropping the egg breaks it apart and can result in a wide variety of different results (highest entropy). If we pick up all the pieces and drop them again, the egg will never reassemble itself.


Collisions between black holes produce gravitational waves which, according to Richard Muller, might reveal 'new' time being created

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Time across the universe

As we look out across space, the limited speed of light means we see objects as they were when light left them at some point in the past - this turns our universe into a cosmic time machine

Earth
Distance:
0km (0 miles)
Time at the object:
Now

The Sun
Distance:
150 million km (93 million miles)
Time at the object:
8 minutes 20 seconds ago

Jupiter
Distance:
At least 588 million km (365 million miles)
Time at the object:
33 minutes ago

Pluto
Distance:
Up to 7.5 billion km (4.7 billion miles)
Time at the object:
Up to 7 hours ago

Proxima Centauri, the nearest star
Distance:
40.1 million million km (25 million million miles)
Time at the object:
4 years 3 months ago

Sagittarius A*, supermassive black hole
Distance:
25,636-light-years away at the centre of the Milky Way
Time at the object:
25,636 years ago (around the peak of Earth's last Ice Age)

Andromeda Galaxy
Distance:
2.5 million light years
Time at the object:
2.5 million years ago (prior to evolution of the human species)

NGC 4845
Distance:
65 million light years
Time at the object:
65 million years ago (around the extinction of the dinosaurs)

MACS J0416.1-2403
Distance:
About 4.95 billion light years*
Time at the object:
About 4.3 billion years ago (shortly after Earth's formation)

Cosmic microwave background radiation
Distance:
46.5 billion light years*
Time at the object:
13.8 billion years ago (shortly after the Big Bang)

*Cosmic expansion has carried the most distant parts of the Universe further away in the time their light has been travelling to reach us.

across the three space dimensions without any effect, so it can be thought of as 'space symmetric' – but the same system is unlikely to be symmetric in time – interactions that increase entropy are inherently more likely than those which reduce it; omelettes rarely reassemble themselves into eggs!

Muller argues that his "Now model" explains the asymmetry of time, whereas traditional cosmology merely defines it by the increase of entropy. Carroll acknowledges the problem, but offers an alternative solution that develops naturally from another hot topic in modern cosmology: "The reason the symmetry problem is so difficult is that you have to start from the idea that the fundamental laws of physics don't play favourites with one direction or the other," he explains. "People again and again fall into the trap of inventing some feature of the Big Bang that purports to explain why the universe had such a low entropy – but they don't explain why that special feature of the past shouldn't also apply to the future."

Carroll's solution, working with his then-graduate student Jennifer Chen, was to look at the problem through the lens of 'eternal inflation'. This is the idea that our universe is not unique, but is merely one among an infinite succession of space-time bubbles that can form and develop spontaneously. "What we did was to say maybe the reason why entropy is increasing is because entropy can always increase. If you treat the universe as a box of gas, then the entropy in the box just goes up and stays there, but if the entropy can always increase, then it becomes a little more natural that we see it increasing – it never saturates," he tells us.

The LIGO experiment tunnels in Louisiana and Washington capture minute shifts in the dimensions of space caused by gravitational waves as they pass through the Earth

"So in that case, why should the way entropy increases look like our Big Bang at the beginning, and develop from there? We suggested that the way the universe increases its entropy is through the creation of baby universes. If you have a universe like ours that expands and cools and empties out, then that empty universe can last forever. Nothing happens in it, but for each tiny region there's a finite possibility in a given time that it disconnects into a little bubble that branches off and goes its own way," he continues. "That little bubble starts small and grows. You go from the old, featureless universe to that plus a bubble – adding that extra little bit increases the overall entropy, but the entropy in that bubble starts off small because it's easier to make a tiny bubble than a big one. Then as it carries on growing, the entropy increases."

In Carroll and Chen's model, the ever-increasing entropy of the universe arises simply because we're trapped inside one of these rapidly expanding bubble universes and unable to see beyond it thanks to the limited speed of light. Cosmic history therefore appears to originate in the low-entropy cosmic fireball of the Big Bang, with entropy increasing as the universe has expanded ever since. Time retains its role as a dimension similar to the three of space, but the arrow of time and increasing energy mean that we can remember the past and make choices (or at least, have an illusion of free will) about the future. "I don't know if this scenario is true," reflects Carroll, "but I would say it's the only one I've ever seen that doesn't beg the question by adding some asymmetry between the early universe and the present."

It's perhaps too soon to say whether Muller's hypothesis of constantly created time, Carroll's explanation for increasing entropy in an eternal universe or some other entirely new theory will ultimately explain the origin of time, but we can all hope that, just as entropy increases, so too will our understanding of this intriguing phenomenon, and our complex relationship with it.

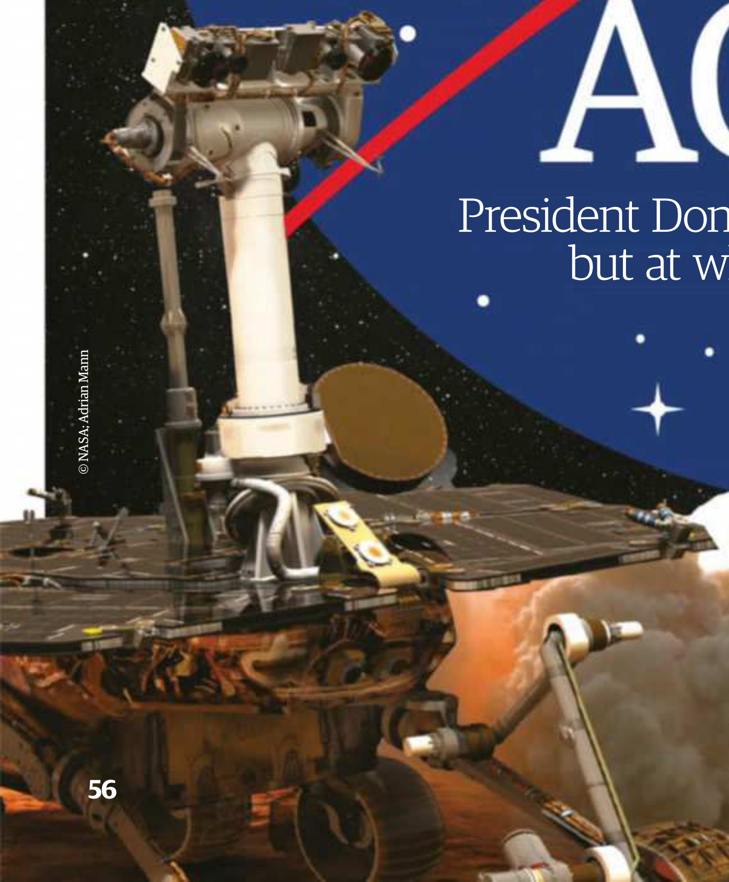
One of the most famous effects of relativity is time dilation: the slowing down of time for objects moving at high speed, relative to observers viewing them from outside

"If you have a universe that expands and cools and empties out, then that empty universe can last forever" **Sean Carroll**

MAKE NASA GREAT AGAIN?

President Donald Trump is aiming for the Moon, but at what cost o space exploration?

Written by David Crookes



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President Donald Trump picked up his pen in the Roosevelt room of the White House and, with typical fanfare, signed his name on the bottom of an important document laying out new policy details for NASA. It was, he said, "exactly 45 years ago, almost to the minute" that Jack Schmitt became one of the last Americans to land on the Moon. "Today," he continued, "we pledge that he will not be the last."

As he finished his speech and showed off his signed paper to the assembly, the focus was once more placed on human space exploration and another long-awaited trip to the lunar surface. "This time," President Trump said, "we will not only plant our flag and leave our footprint, we will establish a foundation for an eventual mission to Mars, and perhaps some day to many other worlds beyond."

It was, in some sense, a retreading of past ambitions. In 1989, to mark the 20th anniversary of the first Moon landing, Apollo 11, President George H.W. Bush announced the Space Exploration Initiative, calling for humans to be sent to the Moon and for astronauts to explore Mars. 15 years later his son, President George W. Bush, pressed for a return to the Moon by 2020, while President Barack Obama sought a 2030 mission to Mars when he was elected to the highest office.

A desire to put American boot's back on our natural satellite is just one of a raft of policies devised by the White House administration. Indeed, Space Policy Directive 1 and the subsequent

President Donald Trump signed the Space Policy Directive 1 on 11 December 2017

Trump administration proposal

President Donald Trump really wants to shoot for the Moon

Increase funding for NASA
The 2019 budget for the National Aeronautics and Space Administration is proposed to increase by $500 million, or 2.6 per cent, to $19.6 billion.

Head for the Moon
The Trump administration is squarely focused on launching American astronauts from US soil and landing them on the Moon, starting with robotic missions in the next few years.

Refocus technology development programs
The emphasis is on supporting space exploration activities, so some space technology development programs will be axed in favour of those fitting the new bill.

Build stronger commercial partnerships
A new $150 million program will begin to support commercial partners and encourage them to develop capabilities that can be used by both the private sector and NASA.

End public funding for the ISS
From 2025, the US government seeks to end direct funding of the International Space Station and instead rely on commercial partners for low-Earth orbit research.

Keep Mars firmly in mind
Trump's administration wants humans to eventually visit the Red Planet. There is also continued support for the next Mars rover (due to launch in 2020) and a plan to retrieve geological samples.

Protect the Earth from asteroids
As part of the continued robotic exploration of the Solar System, there is a proposal to spend $150 million on a planetary defense program to head off threats from asteroids.

But don't land on one
NASA's funding for the Asteroid Redirect Mission – which was the foundation of Trump's predecessor Barack Obama – has already been axed.

Fiscal Year 2019 agency budget maps a fresh, future direction for the US space agency while determining how NASA's budget will be spent over the coming years.

They also formalise the suggestions put forward by the newly reinstated National Space Council, headed by Vice President Mike Pence. In that context, landing an astronaut on the Moon again could be seen as merely a headline, albeit a very important one. "Human spaceflight is often easier for people to connect to," explains Alan Steinberg, a political scientist at Rice University and an expert on NASA policy. "People can relate to the idea of a man on the Moon more so than a rover on Mars."

Such a direction, he continues, lends an element of prestige, even though Steinberg believes it could be viewed as an easy victory. "The refocus on human exploration is also likely a political move: America is sending people into space and not just Russia and China," he says.

The Presidential Memorandum on Reinvigorating America's Human Space Exploration Program, to give it its full title, replaced a single paragraph in the 2010 National Space Policy guidelines. It scrapped the plan to send humans to an asteroid by 2025 and it removed the mid-2030s timeline for sending humans to orbit Mars. In its place was the directive to go beyond low-Earth orbit, with the Moon the first destination, and it spoke of using "commercial and international partners to enable human expansion across the Solar System."

Few are surprised that the Asteroid Redirect Mission, introduced in 2013, is not being continued – it was given notice of defunding last April. Devised in order to send a robotic crew to a near-Earth asteroid, grab a rock from it and redirect it to a stable orbit around the Moon, the idea was to allow astronauts to use that rock in the 2020s as a testing ground in preparation for a Mars mission. Yet, according to Casey Dreier, director of space policy for The Planetary Society, it was never popular with congress, or the scientific community.

"It was an example of a program being rolled out without a lot of groundwork being done to get a ton of support for it," he tells us. "It never really got a lot of people excited and not that much had been done to advance the project, which I guess kind of tells you what the internal opinion was about how successful it was going to be." The significance of finally scrapping it, however, is that the official US policy – for astronauts to explore asteroids – is now no longer a priority.

> "People can relate to the idea of a man on the Moon more so than a rover on Mars" **Alan Steinberg**

Dreier says it will have "trickle-down implications for the entire government and private space sector" because all of their efforts will now be on lunar exploration. This, in turn, will have implications for another aspect of NASA: the maintenance of the International Space Station (ISS). "NASA only has the money to afford to carry out one human spaceflight program really well," Dreier says. As such, President Trump wants to end US funding for the ISS by 2025.

"The President wants to turn over the role of providing low-Earth orbit microgravity research capability to the private sector," explains Frank Slazer, vice president of Space Systems at the Aerospace Industries Association. Indeed, the 2019 budget proposal includes $150 million to "encourage commercial development" on the space station so that NASA ends up relying on private partners.

However, the plan has run into resistance. Democratic Senator Bill Nelson suggests the White House will have a "fight on its hands" and even the aerospace industry is opposing the move. "In my view it's premature to definitively plan to stop funding the ISS since this could have a chilling effect on commercial researchers in the near term who may see the future availability of a research platform to be uncertain," Slazer tells us. "These commercial researchers are key to any future commercialisation of low-Earth orbit, so discouraging them could be counterproductive."

Slazer is also concerned about how the US would engage with its international partners. "I think fully privatising the US part of the ISS would be very problematic since we have commitments to provide resources such as power and thermal management to our international partners – in fact, when a non-Russian astronaut goes to the ISS, its paid for by NASA. Additionally, the ISS has a wide range of government research functions such as astrophysics research for which no commercial market exists."

The ISS is by no means the only NASA project or mission negatively affected by the Trump administration's proposed change of direction for NASA. The budget for 2019 is $19.6 billion, up $500 million or 2.6 per cent on 2018, and, of that, $10 billion will support human space exploration. Yet, as Dreier points out, that's a small boost for human-based missions: "At best, maybe a 10 per cent bump up in terms of that program's budget."

To pay for that, however, it appears cuts are being made in numerous areas. There will be a

The proposals will keep the SLS and Orion on track for a test launch by 2020 and crewed missions around the Moon by 2023

Ivanka Trump handles a sample of the Moon

What the experts think

Is NASA's fresh direction reaching for the stars or about to bump back down to Earth?

Dr Mary Lynne Dittmar
President and chief executive of the Coalition for Deep Space Exploration
"After 45 years, it is time to return humans to the region of the Moon, even as we look toward Mars. The Coalition is proud to support NASA and to help bring about this

Dr Karan Jani
Gravitational wave astrophysicist
"One day humanity has to decide if it wants to understand the entire universe (and use this knowledge to enhance education) or adventure on a limited patch of Solar System."

Robert Lightfoot
Acting NASA Administrator
"This proposal provides a renewed focus to our human spaceflight activities and expands our commercial and international partnerships, while also continuing our pursuit of cutting-edge science and aeronautics breakthroughs at the core of our mission."

Senator Bill Nelson
Senior United States senator
"Turning off the lights and walking away from our sole outpost in space [the International Space Station] at a time when we're pushing the frontiers of exploration makes no sense."

Cuts and boosts

There were some inevitable winners and losers in the wake of the Trump administration's NASA proposals

Lunar Discovery and Exploration program

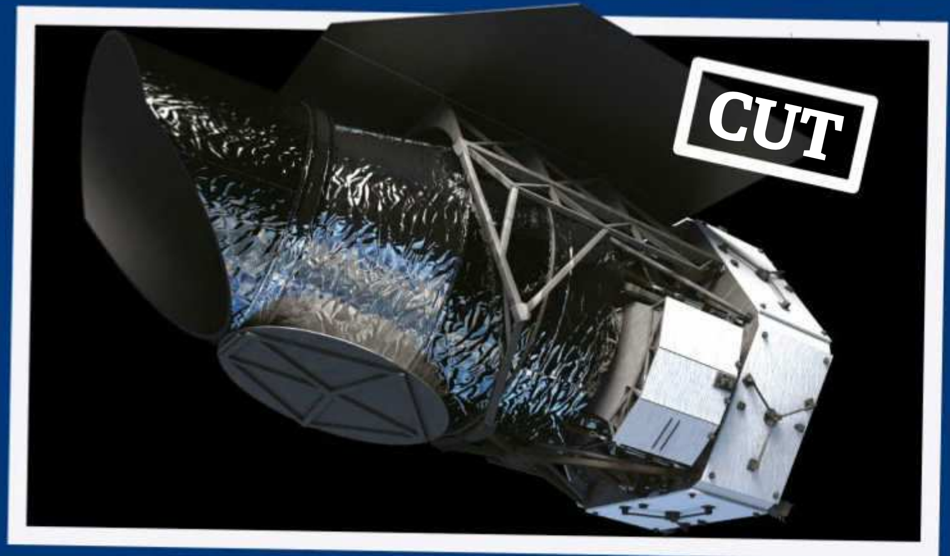
According the budget proposals, a new robotic lunar exploration mission "would support innovative approaches to achieve human and science exploration goals." It says the idea is to pump money into the funding of contracts for transportation services, as well as into the development of small rovers and instruments that will meet the needs of lunar scientists.

Who will be affected?

Those working on ISS missions – the US part of the space station will be put into private hands as the focus switches to the Moon.

What it means for the future of space exploration

There will be greater attention on the Moon, complemented by the foundation of a Lunar Orbital Platform-Gateway for long-term exploration of our satellite.



WFIRST space telescope

The Wide-Field Infrared Survey Telescope (WFIRST) is under severe threat, with the proposals looking to completely axe what would be NASA's next flagship astrophysics mission after the James Webb Space Telescope. If it got off the ground, it would help discover thousands of new Type 1a supernovae and help astronomers to better understand galaxies, dark matter and dark energy. Yet the White House has baulked at spending more than $3 billion on the project, saying the space-based observatory "would have required a significant funding increase in 2019 and future years."

Who will be affected?

Astrophysicists who in 2010 said WFIRST was a top mission priority and would open the door for an unscripted discovery.

What it means for the future of space exploration

Axing WFIRST – which would have 100-times the field of view of Hubble's infrared instrument – will affect future studies of exoplanets and dark energy.

Investigations of other planets

High-profile planetary missions will continue under the proposed budget. There is support for the next Mars rover, which will launch in 2020 and $50 million will be spent on exploring the possibilities for retrieving geological samples from Mars. Cash will continue to be poured into the Europa Clipper, an interplanetary flyby mission in development by NASA to study the Galilean moon Europa, although there's no mention of support for the Europa Lander. The words "and beyond" are also frequently used in relation to the Moon.

Who will be affected?

All of those working on the missions to Mars and beyond since there appears to be a desire to continue exploring the wider Solar System.

What it means for the future of space exploration

Solar System exploration remains a top priority.

proposed transition away from NASA's current government-owned and operated fleet of communications satellites and associated ground stations in favour of commercial capabilities, while development of the Wide-Field Infrared Survey Telescope (WFIRST) is also set to be axed.

WFIRST was due to launch some time in the mid-2020s. More powerful than the Hubble Telescope, it was designed to search for and study planets around other stars and let NASA study the biosignatures of those distant bodies – something which could point to the potential of life. President Trump's administration believes the $8.8 billion James Webb Space Telescope – which it will continue to fund – makes WFIRST unnecessary and that a significant funding increase would otherwise be needed, but many astronomers beg to differ.

Indeed, David Spergel, a physicist at Princeton University and co-chair of the WFIRST science team, tweeted: "Abandoning WFIRST is abandoning US leadership in dark energy and exoplanets." He also said keeping WFIRST would help to address big questions such as "what is driving the acceleration of the universe, what are the properties of exoplanet atmospheres, how did our galaxy and its neighbours form and evolve and what determines the architecture of exoplanets?" He urges the astronomy community to "push back," and others appear to agree that they should.

"WFIRST will help astronomers understand dark energy better and work has already begun on it," Dreier tells us. "The budget proposal is explicitly saying, 'look, we have to put money into human exploration and so we took it out of the science mission' and that is an unforced error in my opinion in terms of prioritisation. This is a clear high-priority mission that would teach us something new about the universe."

Supersonic X-Plane

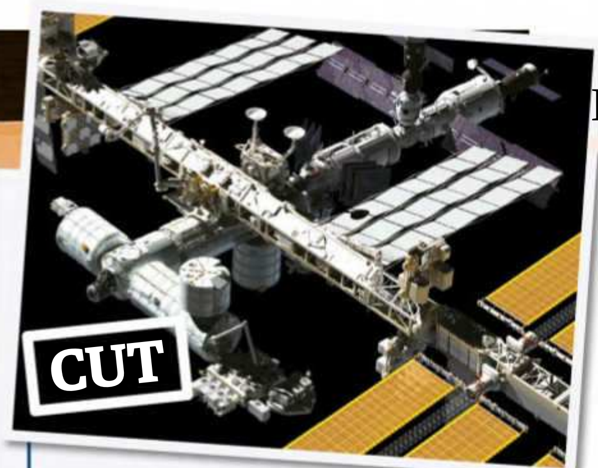
The budget proposals threw their weight behind the development of the Low-Boom Flight Demonstrator, an experimental supersonic airplane due to make its first test flight in 2021. It would fly at Mach 1.4, and aims to eliminate the very distinctive, ear-splitting sonic boom made when the sound barrier is broken. Just as important, the Trump administration is also increasing funding into hypersonic flight, which is five-times the speed of sound, for possible applications in national defense.

Who will be affected?

Anyone working in – or seeking to work in – the commercial airline industry since it is likely to create and sustain employment in this area.

What it means for the future of space exploration

Hypersonic research allows for better understanding of how crewed and robotic spacecraft can safely enter and exit the atmosphere of a planet.



International Space Station

Direct US financial support for the ISS will end in 2025. The idea is private space companies and other countries will step forward to fill the funding gap. $150 million will be offered to support commercial partners, which will come with a condition that NASA can continue using the ISS to carry out science experiments in space. This means the cut is not a matter of axing the space agency's involvement in the ISS but, with the budget also proposing a greater reliance on commercial communications satellite capabilities, it does show the extended desire for private partnerships.

Who will be affected?

Everyone involved with the ISS. Currently the US spends around $3.5 billion each year on the ISS while Russia, Canada, Japan and Europe contribute some $1 billion combined.

What it means for the future of space exploration

Astronaut Mark Kelly reckons other countries will fill the void and "change the direction of the world's collective space endeavours."

Five Earth Science missions

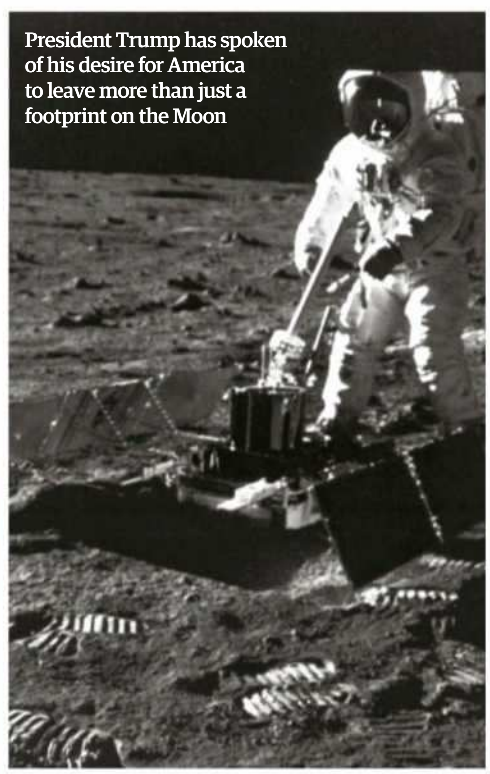
As well as eliminating NASA's Office of Education, five Earth Science missions are also getting the chop. They are the Radiation Budget Instrument (RBI); the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE); the Orbiting Carbon Observatory-3 (OCO-3); the Deep Space Climate Observatory (DSCOVR) Earth-viewing instruments and the Climate Absolute Radiance and Refractivity Observatory (CLARREO) Pathfinder – all of which measure the Earth's climate. It's a shift in focus away from home in favour of deep-space exploration, although the budget nevertheless proposes $1.8 billion in Earth science spending overall, the same as allocated for the 2018 budget, but $102 million less than the 2017 budget.

Who will be affected?

Earth scientists, and especially those working on the five missions which are being cut (and, in terms of education cuts, students).

What it means for the future of space exploration

Reducing investment in Earth sciences has been called a major setback that would take us back to the pre-satellite era.



President Trump has spoken of his desire for America to leave more than just a footprint on the Moon

© NASA; Adrian Mann

Make NASA great again?

Meanwhile, NASA's Office of Education and five Earth-science missions are also due to be terminated. This would lead to the loss of the Radiation Budget Instrument; the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) satellite mission; the Orbiting Carbon Observatory-3 experiment; the Deep Space Climate Observatory Earth-viewing instruments and the Climate Absolute Radiance and Refractivity Observatory Pathfinder.

"It is disturbing that NASA funding is being cut for Earth-science missions," laments Professor Sidney Hemming of the Lamont-Doherty Earth Observatory at Columbia University. "In general the deteriorating levels of government funding for Earth sciences is very concerning. It is leading to problems maintaining the careers of researchers, and it will lead to losing students in STEM fields."

She tells us that the cuts are "direct hits on climate change research and consistent with what we've been hearing about this administration's distaste for such studies." The budget proposal, however, says it will lead to a focused and balanced Earth-science program, benefiting to the tune of $1.8 billion, which will be used to maintain the United States' "45-year record of space-based land imagery by funding Landsat 9 and a Sustainable Land Imaging program."

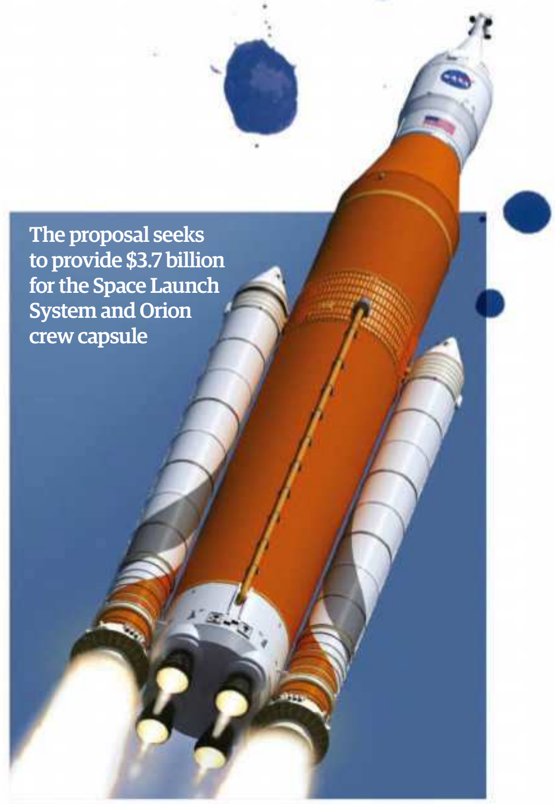
It is unlikely that private enterprises will step in to work on projects such as those since their attention will be focused on more profitable missions. Questions are therefore being asked about what companies can get out of the Moon – "maybe you can get water out of the surface and get rocket fuel out of it," Dreier suggests – and whether it's worth the trade-off.

There does appear to be a recent scramble to work on the lunar surface. China has successfully sent three robotic landers over the past ten years, and the Space Act of 2015, passed under President Obama's watch, paved the way for mining on other worlds in what was seen as a challenge for the international treaty on outer space.

"I personally don't understand the scientific value of Moon first," says Steinberg, "but I can see the political value as it likely resonates with the average person better to think about people on the Moon versus people on asteroids." He also points out that we are at a time when there are no active astronauts who have set foot on the Moon. "With other countries targeting the Moon this is both an issue of prestige as well as arguably a technological stepping stone," he tells us.

"Doing it with private sector partners is a way to possibly do it cheaper and involve the commercial space world more. If space will ever be something for people like you and me to explore there needs to be more commercial endeavours, and that means bringing in the private sector to be involved."

As always, though, the NASA plans are more about realigning what the space agency should be doing with the resources it has rather than new directives with new funding. "I also think the fact that NASA will get a modest increase in its budget shows a very supportive administration broadband, and that's a good thing," Dreier tells us. "But I think ultimately there are enough resources to do a lot of these without having to pick and choose."



The proposal seeks to provide $3.7 billion for the Space Launch System and Orion crew capsule

The Office of Education, which costs $100 million and seeks to attract and retain STEM students and engage Americans in NASA missions, is being axed

The budget proposes a $150 million planetary defense program to protect Earth from asteroids

OPPORTUNITY BREAKS A MARTIAN RECORD

For the 5,000th time, NASA's Mars Exploration Rover has seen a Red Planet sunrise during its journey across alien terrain

On the 16 February 2018, NASA celebrated its Mars Exploration Rover Opportunity seeing in its 5,000th Martian day, also referred to as a sol, on the Red Planet. The rover, having now surpassed its initial mission by over 4,910 sols, is still being powered by the rays of our Sun as it makes its way across Mars' dry and rocky surface.

Opportunity and its sister rover, Spirit, both landed on the surface of Mars in January 2004. Spirit couldn't cut it in comparison to the longevity of Opportunity; it only lasted until 22 May 2011 and travelled a total of 7.7 kilometres (4.8 miles). Opportunity, however, is continuing its way around the western rim of the enormous Endeavour Crater and is currently carefully analysing a region called 'Perseverance Valley'.

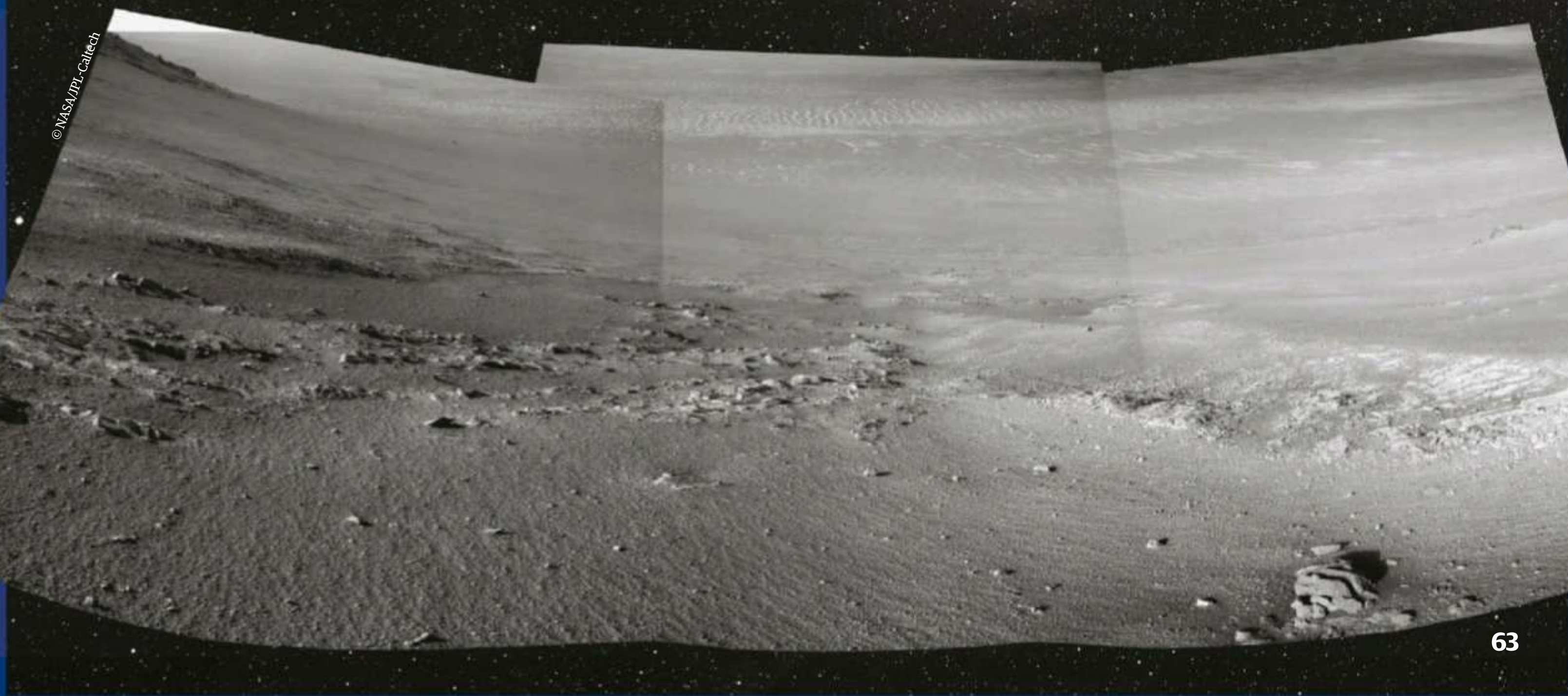
In February 2018, over 14 years after it landed on the alien landscape, Opportunity has relayed images, taken with its front Hazard Avoidance Camera, back to Earth showing a region covered in soil and gravel arranged in an intriguing stripped pattern. This pattern may have been the result of wet soil sculpting the surface of Perseverance Valley many years ago.

"Perseverance Valley is a special place, like having a new mission again after all these years," says Ray Arvidson, Opportunity deputy principal investigator at Washington University in St. Louis, US. "We already knew it was unlike any place any Mars rover has seen before, even if we don't yet know how it formed, and now we're seeing surfaces that look like stone stripes. It's mysterious. It's exciting. I think the set of observations we'll get will enable us to understand it."

Even after all this time, the old rover can still reveal surface surprises that grab the attention of astronomers worldwide. Although it is possible the rock stripes could have also been the result of wind, material down flow or a combination of both, it singles out interesting targets for future Martian missions to study in their search for water on Mars. The never-ending search for water, or even signs for previously existing water, on Mars has been heavily influenced by the close-up investigation of Opportunity. It has even collaborated with Martian orbiters in an attempt to find potentially compelling regions. For instance, in 2010 the Opportunity rover teamed up with NASA's Mars Reconnaissance Orbiter in order to examine the Santa Maria Crater, as they were hoping to find water-bearing minerals. Unfortunately the results did not bring any groundbreaking news.

Still, Opportunity soldiers on but its solar panels are slowly becoming more and more inefficient. They could originally provide the rover with 900 watt-hour. Now, as it only produces 283 watt-hour, scientists have to be more considerate when navigating the rover. Regardless, the rover notched up a miraculous 45 kilometres (28 miles) on its travels, exceeding a Martian marathon and outclassing all other extraterrestrial rovers.

The recently discovered 'rock stripes' could be a consequence of wet soil on the ancient Martian surface



SPOT A FAKE SPACE PHOTO

How can you tell if that sensational space image is real or fake? Written by Stuart Atkinson

Spot a fake space photo

If you use social media you will know it is dominated by two types of images – pictures of cats and photographs of anything to do with space. Every platform has thousands of members who enthusiastically share photographs taken through the International Space Station's windows, by space probes on or orbiting planets and through telescopes. Many are jaw-droppingly beautiful, and when a photo of the northern lights blazing above snow-capped Canadian mountains or a view of a copper-hued eclipsed Moon hanging above a city skyline pops up on our timelines it is always a pleasant surprise, and a welcome distraction from our everyday troubles. If there's a cat in it, even better...

Unfortunately, many astronomical images posted online are not what they appear to be. Some are genuine, but stolen from other people. Others are composites, impressive but unrealistic combinations of several different genuine photos to make something inaccurate or scientifically impossible. Others still are purely digital creations, produced inside computers with not a camera in sight.

Why do people create, or knowingly share, these fake images? Some do it because they are attention seekers who want to be popular on social media; they want as many 'likes' or 'shares' as possible. A few do it because they don't have the equipment, experience or skill needed to create genuine images, or they do but they are too lazy to learn how to take them themselves. Others are looking for financial reward. The media loves breathtaking images of eclipses, a bright shooting star or a display of the northern lights, and sometimes will even pay for them. Unfortunately, many of the people who select images for use have very little, if any, astronomical knowledge, so they don't know which images are real and which are fake. Some, to be perfectly honest, don't care; as long as an image is colourful and dramatic they'll use it.

Before we look at how to spot these fakes and prevent yourself from being fooled – and maybe even unwittingly spreading them more widely across the internet – a short history lesson...

It used to be all but impossible to fake a space image, especially astrophotographs of objects in the night sky. In the old days cameras held coiled-up strips of light-sensitive film which was then processed in tanks of chemicals to produce prints, or slides. Those photos were essentially one offs, printed in books and magazines and couldn't be copied. Today, sky watchers routinely fire off dozens or even thousands of images in one night without the old worries about running out of film. Now we process our images on our computers, then post them online for others to enjoy – and where any Tom, Dick or wannabe astronomical Ansell Adams can steal them with a click of a mouse or a tap of a finger, either claiming them as their own or using them to make another image.

Today there are so many stolen or faked images out there that you might think spotting one is like looking for a needle in a haystack. No, not quite. In fact, once you know what to look for it's surprisingly easy to tell if an image is fake or not, especially when it comes to astrophotographs of the night sky.

First of all, it's a bit suspicious if someone posts an awe-inspiring wide-field image of the night sky, or a stunning portrait of a galaxy or a nebula, out of the blue

without any previous references to taking such photos or having shown previously they have the equipment needed to take them. Most people take poor or even rubbish photos when they start, and the quality of their work improves as they build up their skills. If someone who has never posted even a simple image before suddenly posts an amazingly detailed one, claiming it as their own, you could be forgiven for raising a Spock-like eyebrow and wondering if they're passing off someone else's work as their own...

Sadly, more and more experienced astrophotographers are having their work ripped off and claimed by others. Some now put digital watermarks on their images, or hide personal symbols or artefacts in them to make them easy to identify if posted in someone else's name.

Some images can be identified as fakes because they are astronomically inaccurate or impossible. It's so easy to add streaks of light to an image in Photoshop that after every meteor shower social media is flooded with images showing a sky full of brilliant shooting stars falling parallel to each other, instead of radiating from a common point as they actually do. I've also lost count of the number of 'stunning images' people have shared with me showing the Milky Way blazing above a scenic landscape at completely the wrong orientation to the horizon for that time of year, or ten-times brighter and more detailed than it can ever appear in real life. Fakers who snip the Milky Way out of one image and blend it into another assume no one will know what they've done, but amateur astronomers can spot a fake image like that from light years away. However, people with no knowledge of the workings of the sky would not spot anything suspicious and share them, genuinely believing they're real.

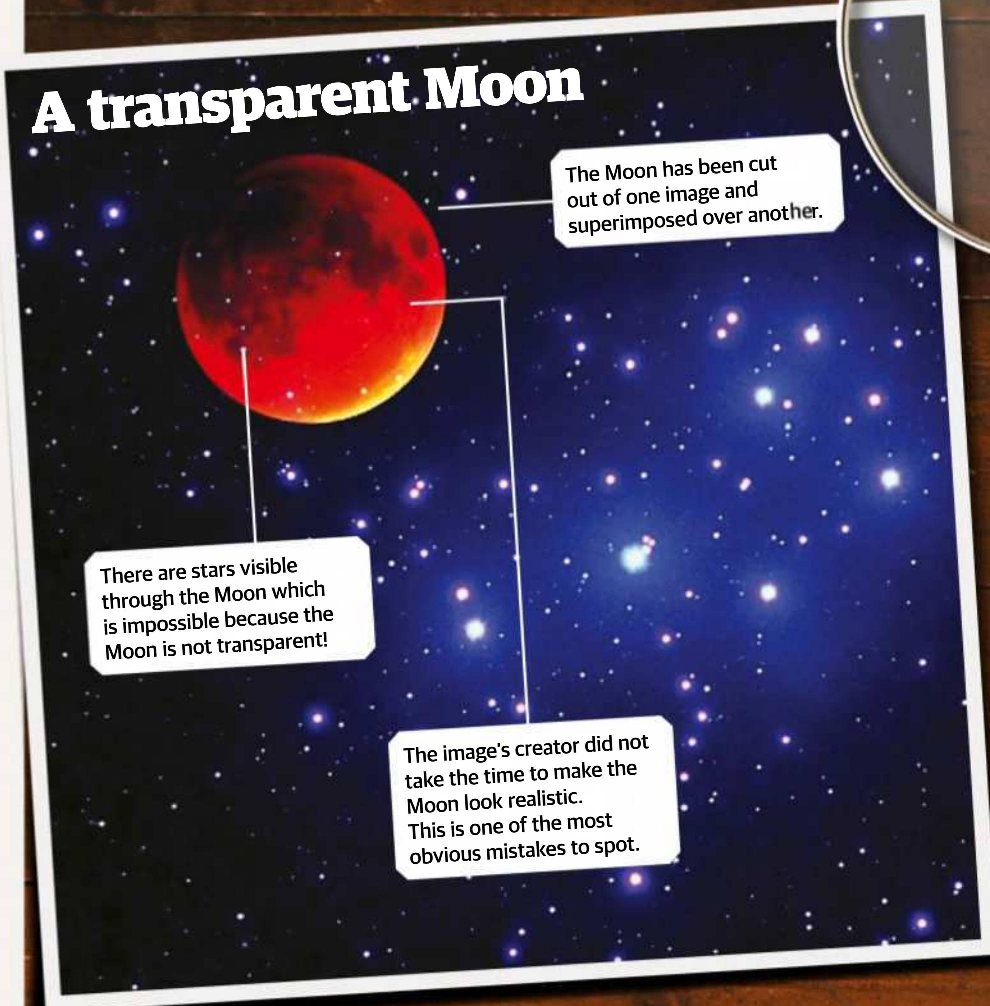
Another giveaway: after every total lunar eclipse Twitter and Facebook groan under the weight of faked images showing the pumpkin-hued Moon glowing in a constellation it simply can't appear in – a sign that the photographer actually made it by cutting an eclipsed Moon out of someone else's photo and then used image processing software to superimpose it on another photo of a star field showing a constellation nowhere near the ecliptic, the path the Moon follows across the sky.

Such 'composite' images are the most common type of fake because they require the least skill to make. Even so, the Moon often trips up the composite-crazy fakers. Dead giveaways of composites include being able to magically see stars through the Moon, spotting that the Moon's reflection in a lake or on the ocean doesn't line up with the actual Moon in the sky or actually seeing the Moon shining in front of clouds. Again, all impossible things even an amateur astronomer can tell are just... wrong.

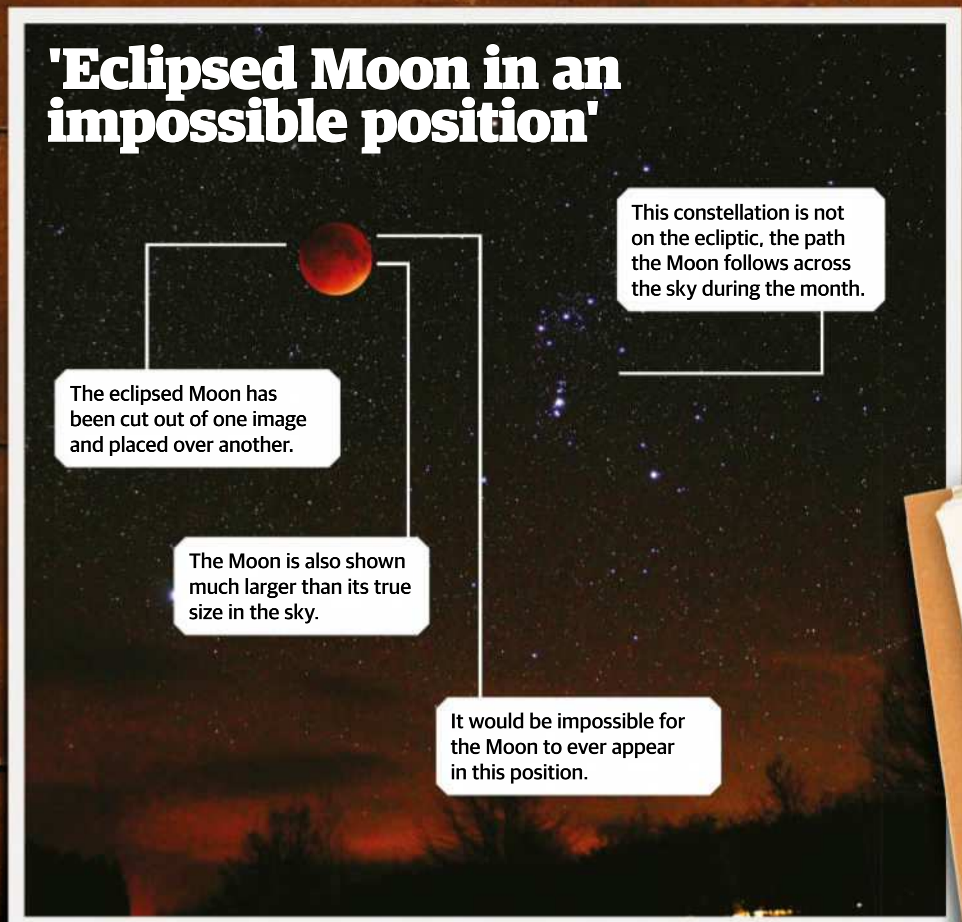
It's easy to spot another genre of fake astronomical photo because they are simply ridiculous. A hugely popular image, shared after every solar eclipse, claims to have been taken "from the Space Station" and shows an enormous eclipsed Sun shining above the Earth with the Milky Way painted across the sky behind it. Another shows an eclipsed Sun with a blood-red corona surrounding it and an aeroplane flying in front of it, somehow fully illuminated!

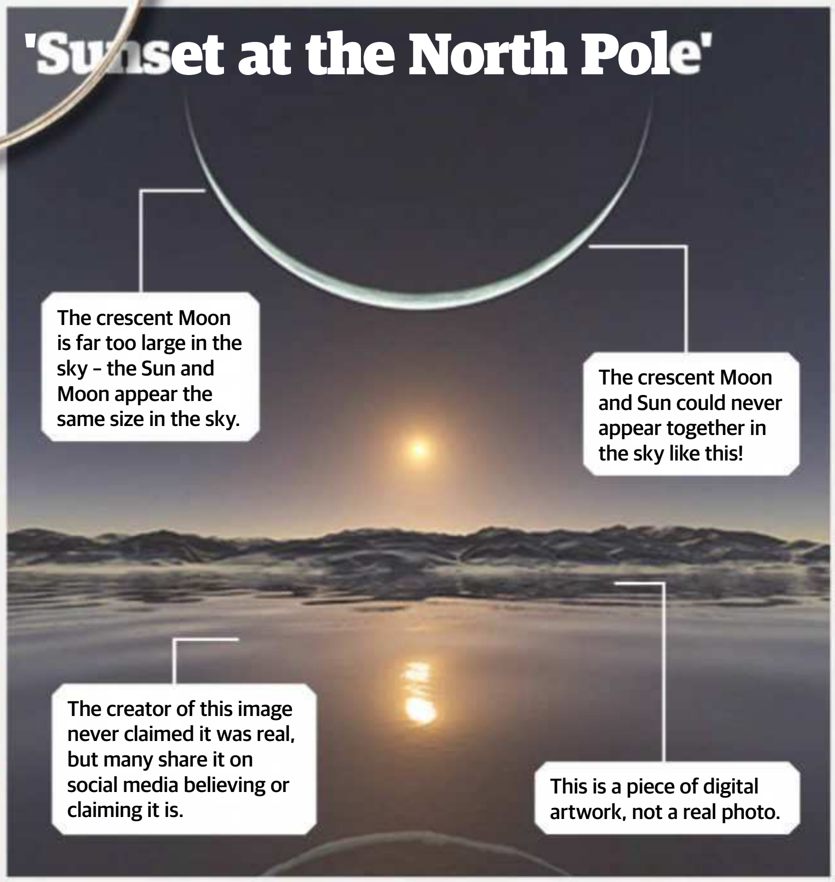
Let's take a walk along an identity parade of fake photos. After studying these you'll be able to spot your own and avoid sharing these classics with the rest of the world.

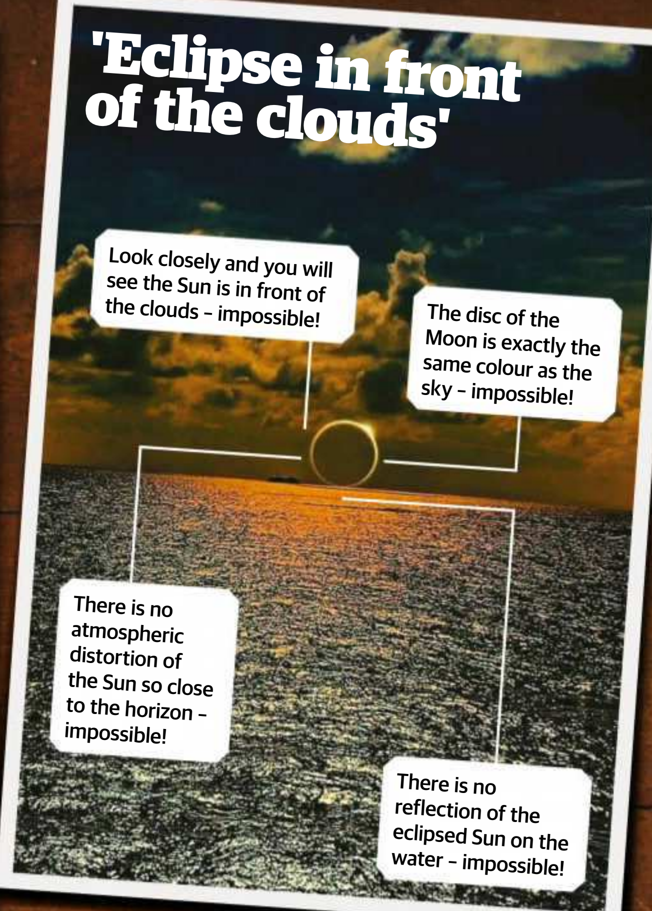
A transparent Moon

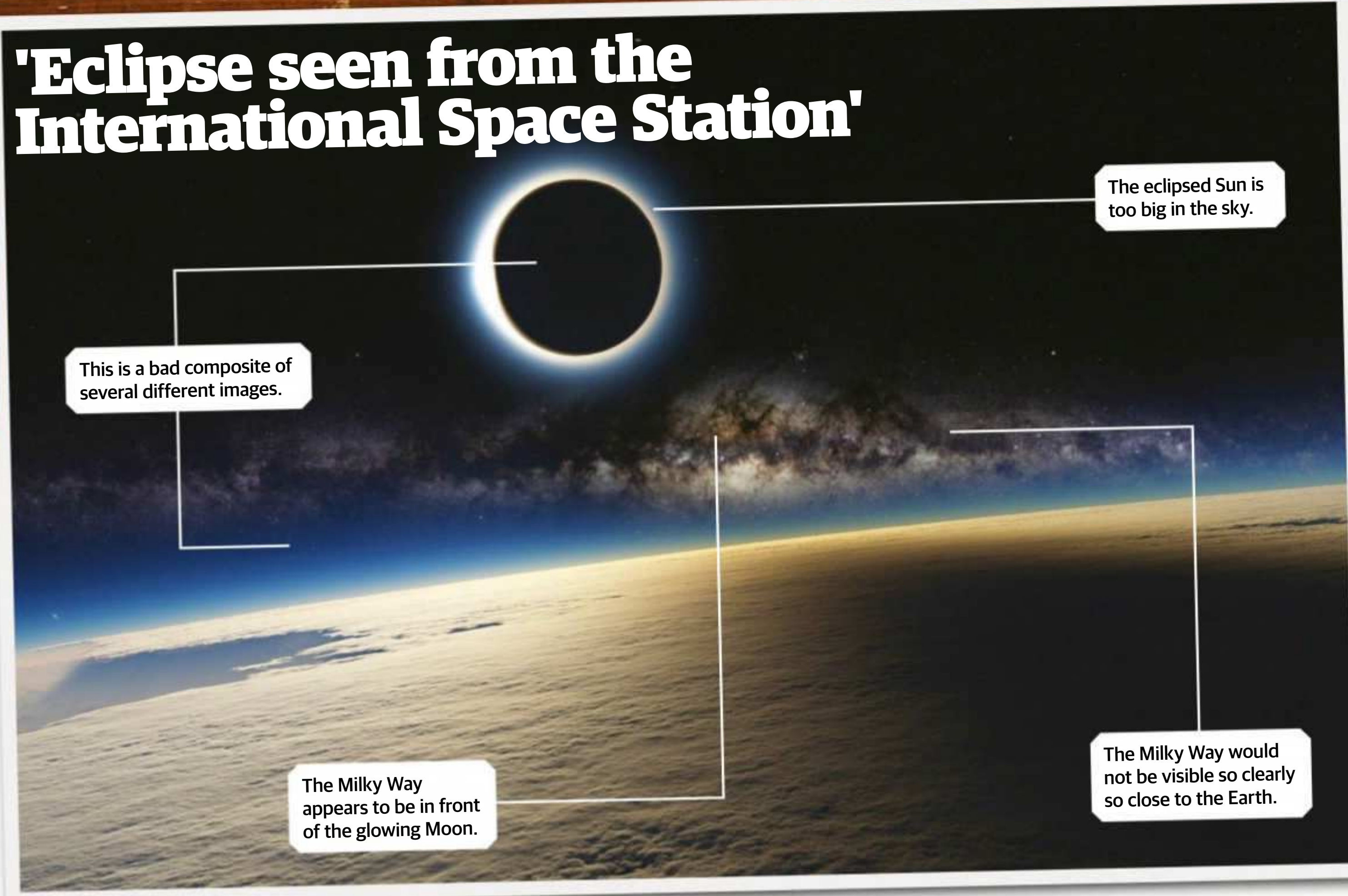


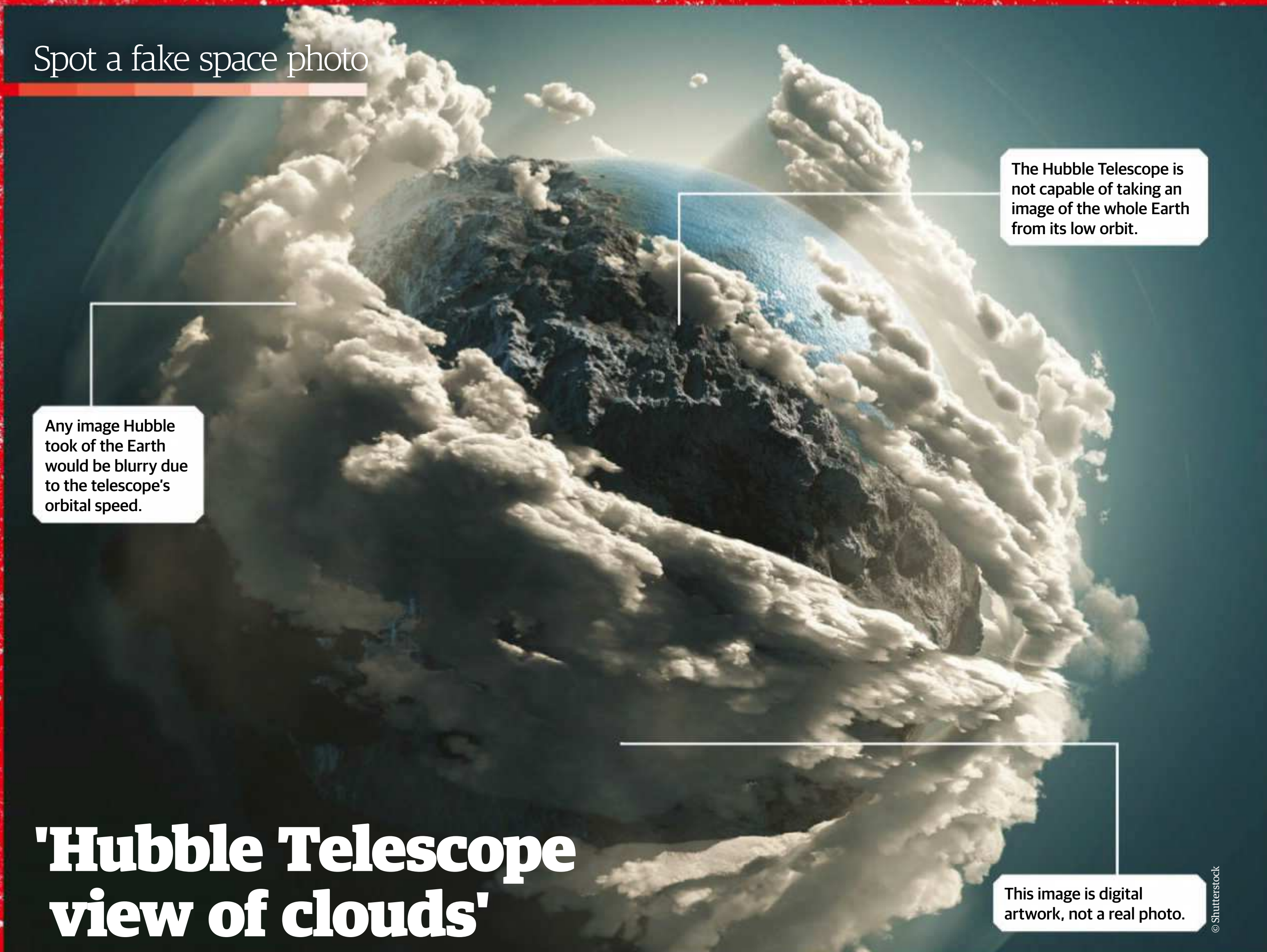
'Eclipsed Moon in an impossible position'



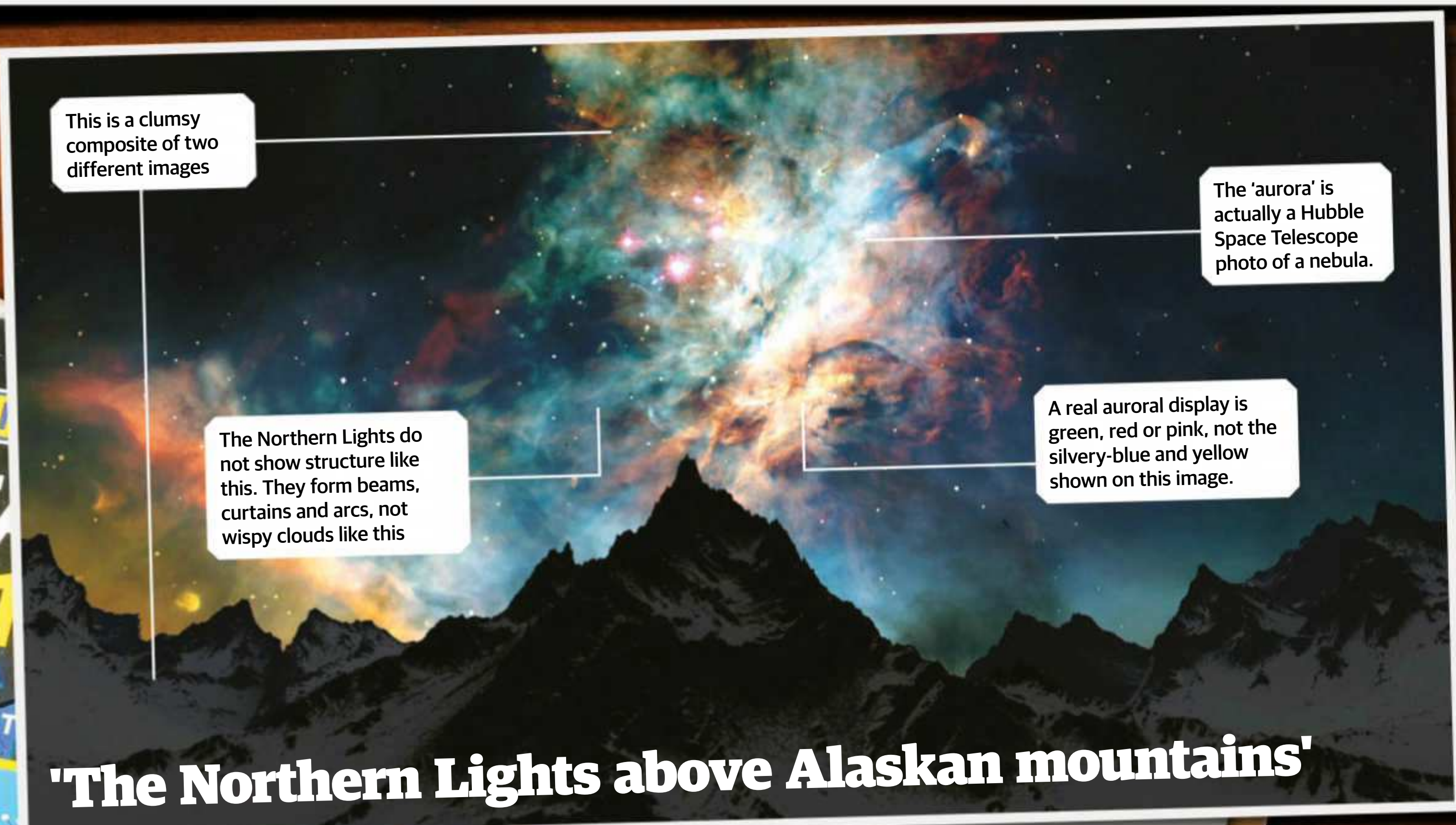

'Sunset at the North Pole'
The crescent Moon is far too large in the sky – the Sun and Moon appear the same size in the sky.
The crescent Moon and Sun could never appear together in the sky like this!
The creator of this image never claimed it was real, but many share it on social media believing or claiming it is.
This is a piece of digital artwork, not a real photo.


'Eclipse in front of the clouds'
Look closely and you will see the Sun is in front of the clouds – impossible!
The disc of the Moon is exactly the same colour as the sky – impossible!
There is no atmospheric distortion of the Sun so close to the horizon – impossible!
There is no reflection of the eclipsed Sun on the water – impossible!


'Eclipse seen from the International Space Station'
The eclipsed Sun is too big in the sky.
This is a bad composite of several different images.
The Milky Way appears to be in front of the glowing Moon.
The Milky Way would not be visible so clearly so close to the Earth.

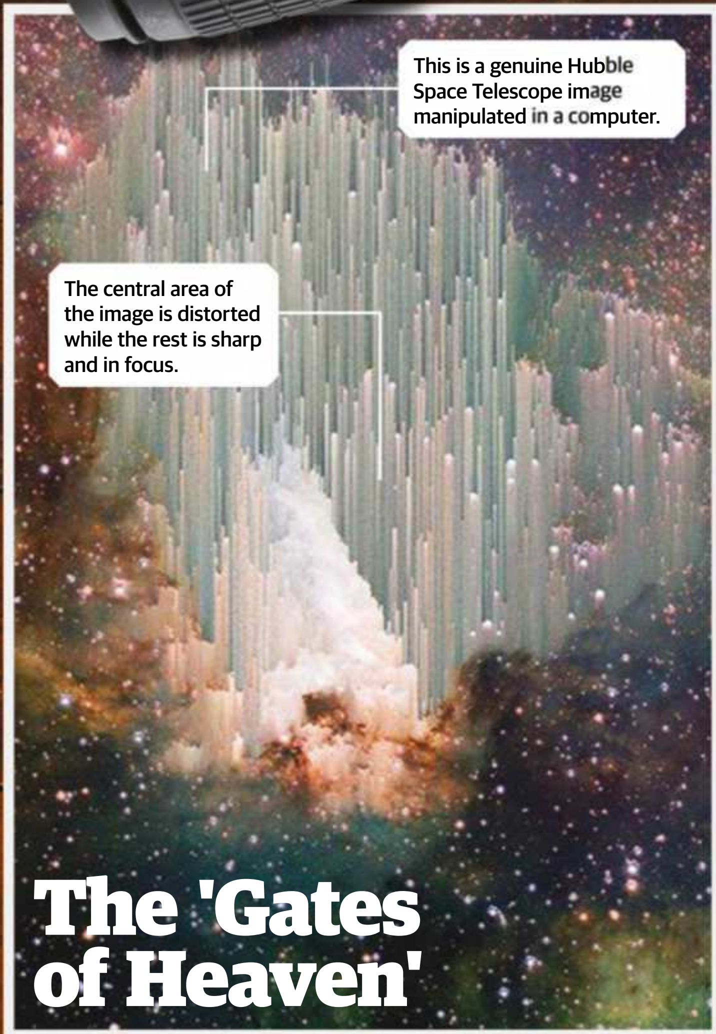


'Hubble Telescope view of clouds'

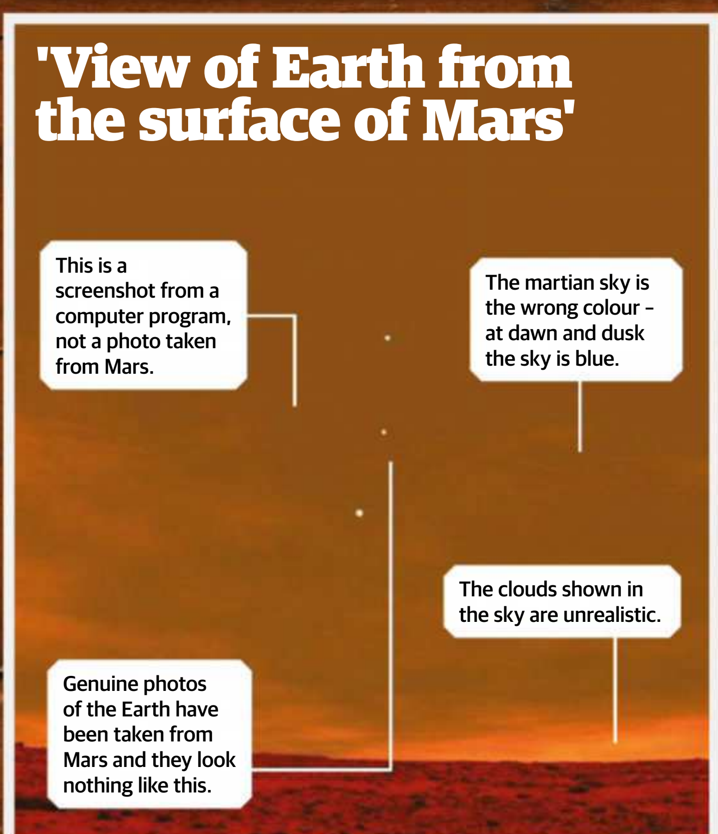


'The Northern Lights above Alaskan mountains'

The 'Gates of Heaven'



'View of Earth from the surface of Mars'



'An amazing meteor shower'

STARGAZER

GUIDES AND ADVICE TO GET STARTED IN AMATEUR ASTRONOMY

In this issue…

What's in the sky

29 MAR
Conjunction between Venus and Uranus in Pisces

1 APR
The Sombrero Galaxy (M104) is well placed for observation in Virgo

1 APR
Comet C/2015 O1 (PANSTARRS) is predicted to reach its brightest at a magnitude of 12.9 in Boötes

4 APR
Spiral galaxy M94 is well placed for observation in Canes Venatici

5 APR
Open star cluster NGC 4755 is well placed for observation in Crux

7 APR
The Moon and Saturn make a close approach, passing within 1°55' of each other in Sagittarius

13 APR
Galaxy Centaurus A (NGC 5128) is well placed for observation in Centaurus

13 APR
Globular cluster Omega Centauri is well placed for observation in Centaurus

14 APR
The Whirlpool Galaxy (M51) is well placed for observation in Canes Venatici

17 APR
Globular cluster Messier 3 is well placed for observation in Canes Venatici

20 APR
Comet C/2016 N^ (PANSTARRS) is predicted to reach its brightest of magnitude 11.2

Jargon buster

Conjunction
A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)
Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)
This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude
An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition
When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation
When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

Red light friendly
In order to preserve your night vision, you should read our observing guide under red light

2 APR
Mars and globular cluster Messier 22 will make a close approach, passing within 0°21' of each other in Sagittarius

2 APR
Mars and Saturn make a close approach, passing within 1°16' of each other in Sagittarius

3 APR
The Moon and Jupiter make a close approach, passing within 3°45' of each other in Libra

7 APR
Conjunction between the Moon and Mars in Sagittarius

12 APR
The Virginids reach their peak at a rate of 5 meteors per hour


© ESO

14 APR
Conjunction between the Moon and Mercury in Pisces

14 APR
Dwarf planet Haumea is well placed for observation in Boötes

16 APR
The Southern Pinwheel Galaxy (M83) is well placed for observation in Hydra

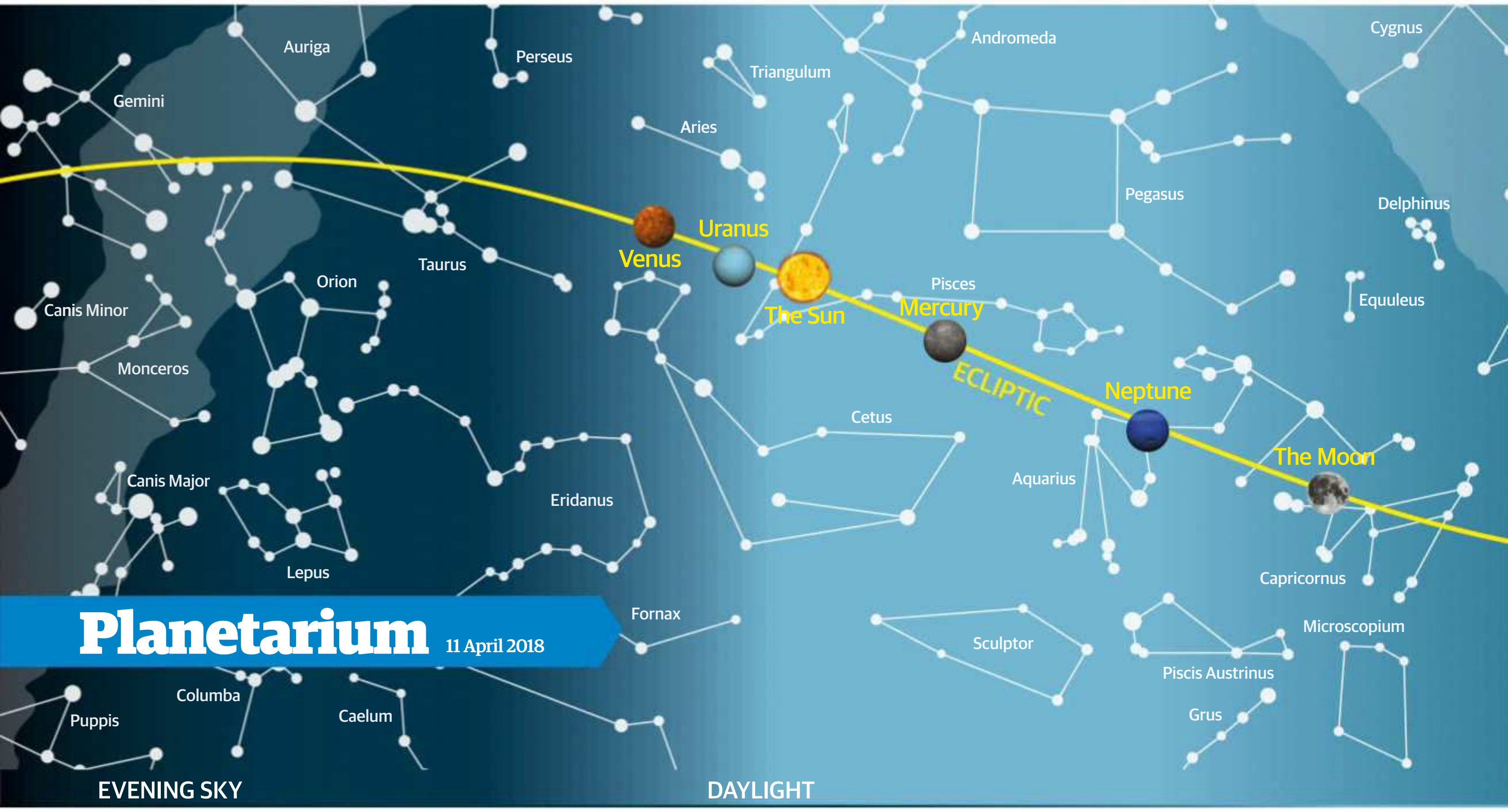
22 APR
The Pinwheel Galaxy (M101) is well placed for observation in Ursa Major

23 APR
The Lyrids reach their peak of 10 meteors per hour

- Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope

STARGAZER

Planetarium 11 April 2018



Moon calendar

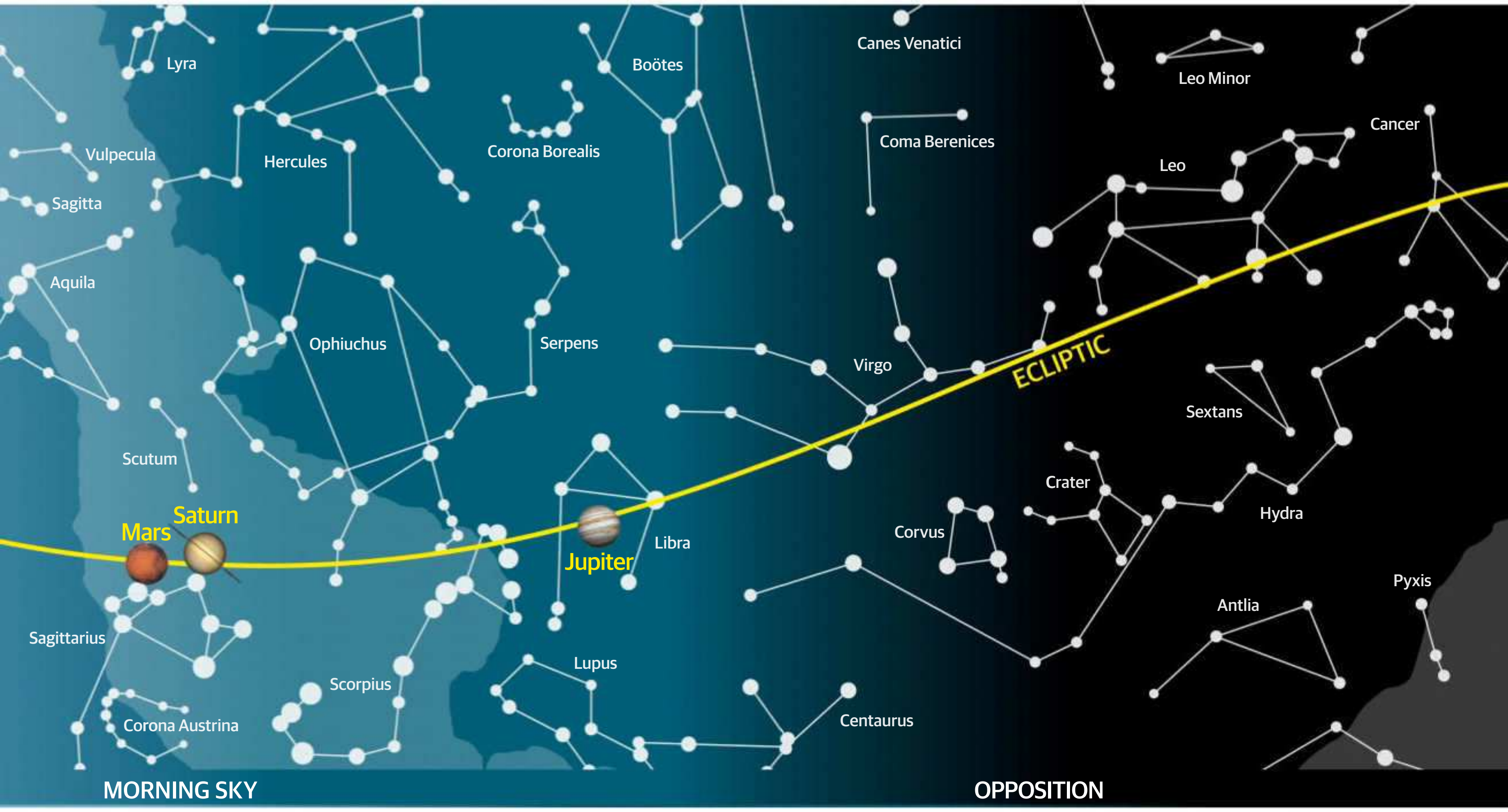
* The Moon does not pass meridian on 30 March

Date	Phase	Illumination	Moonrise	Moonset
29 MAR		96.9%	19:26	06:10
30 MAR	FM	--.--%*	18:16	06:37
31 MAR		99.5%	19:31	07:02
1 APR		99.5%	20:44	07:26
2 APR		97.1%	21:55	07:50
3 APR		92.5%	23:04	08:16
4 APR		86.1%	--:--	08:45
5 APR		78.4%	00:09	09:17
6 APR		69.6%	01:10	09:55
7 APR		60.3%	02:05	10:39
8 APR	LQ	50.6%	02:53	11:29
9 APR		40.9%	03:35	12:25
10 APR		31.4%	04:11	13:25
11 APR		22.6%	04:42	14:30
12 APR		14.6%	05:09	15:37
13 APR		8.1%	05:33	16:46
14 APR		3.3%	05:56	17:58
15 APR		0.6%	06:19	19:11
16 APR	NM	0.4%	06:44	20:27
17 APR		3.0%	07:10	21:43
18 APR		8.2%	07:41	23:00
19 APR		15.8%	08:18	--:--
20 APR		25.5%	09:04	00:13
21 APR		36.6%	09:59	01:19
22 APR	FQ	48.4%	11:03	02:16
23 APR		60.2%	12:14	03:04
24 APR		71.2%	13:28	03:42
25 APR		81.0%	14:44	04:14
26 APR		89.0%	15:59	04:41

% Illumination
Moonrise time
Moonset time

FM Full Moon
NM New Moon
FQ First quarter
LQ Last quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage

	04 APR	11 APR	18 APR	26 APR
MERCURY	0%	10%	20%	40%
VENUS	90%	90%	90%	90%
MARS	90%	90%	90%	90%
JUPITER	100%	100%	100%	100%
SATURN	100%	100%	100%	100%

Planet positions

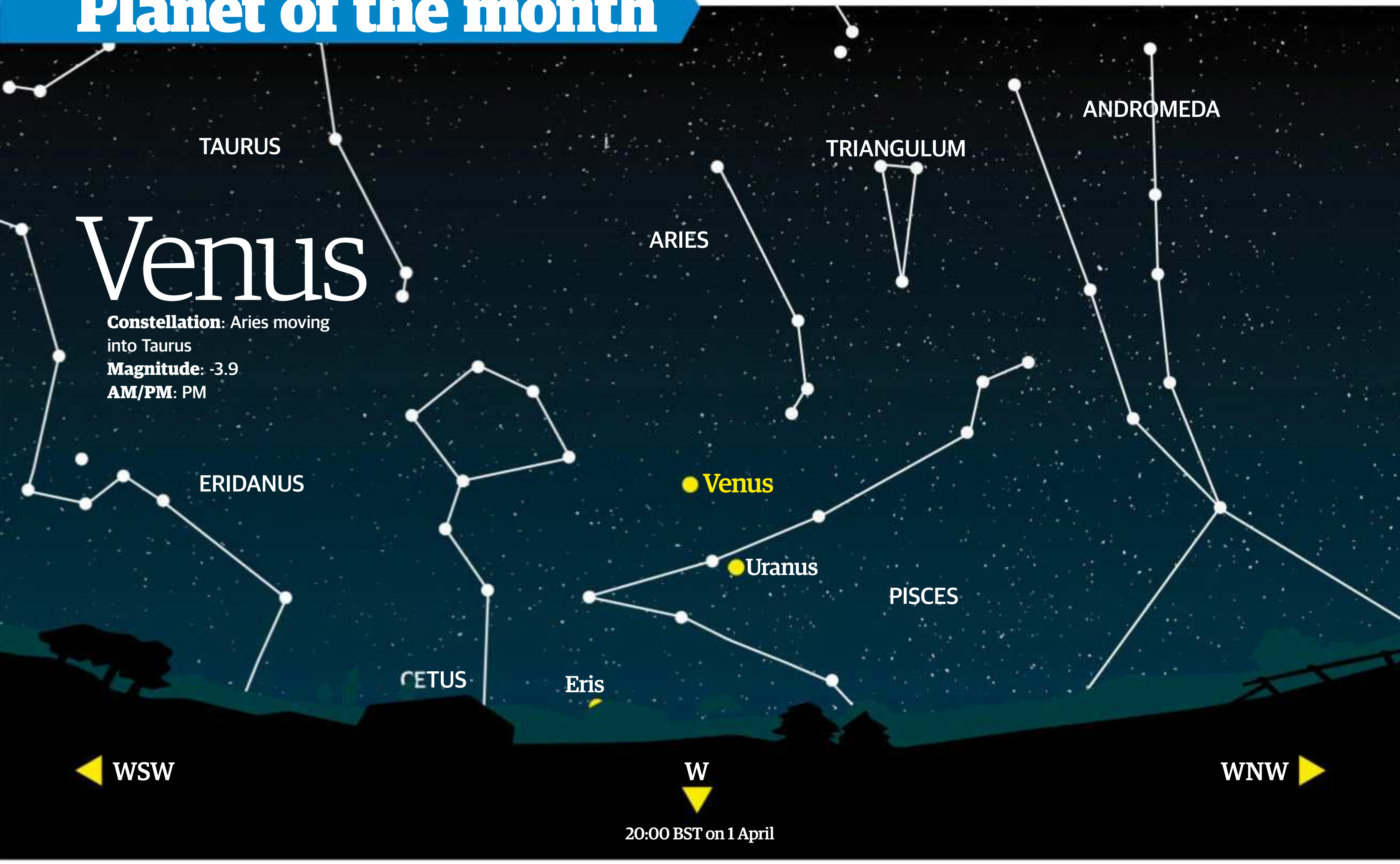
All rise and set times are given in BST

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	29 Mar	00h 48m 17s	+08° 47′ 54″	Pisces	4.2	06:43	20:19
	04 Apr	00h 32m 23s	+06° 04′ 48″	Pisces	5.3	06:18	19:25
	11 Apr	00h 18m 51s	+02° 38′ 25″	Pisces	2.6	05:54	18:27
	18 Apr	00h 19m 32	+00° 50′ 42″	Pisces	1.2	05:36	17:51
	26 Apr	00h 46m 37s	+02° 01′ 46″	Cetus	0.4	05:14	17:41
VENUS	29 Mar	01h 41m 15s	+09° 51′ 37″	Pisces	-3.9	07:30	21:17
	04 Apr	02h 09m 10s	+12° 39′ 45″	Aries	-3.9	07:20	21:36
	11 Apr	02h 42m 22s	+15° 41′ 56″	Aries	-3.9	07:08	21:59
	18 Apr	03h 16m 24s	+18° 25′ 03″	Aries	-3.9	06:59	22:21
	26 Apr	03h 56m 20s	+21° 02′ 44″	Taurus	-3.9	06:51	22:46
MARS	29 Mar	18h 26m 47s	-23° 33′ 52″	Sagittarius	0.3	03:16	11:05
	04 Apr	18h 41m 12s	-23° 31′ 20″	Sagittarius	0.2	03:06	10:56
	11 Apr	18h 57m 36s	-23° 23′ 54″	Sagittarius	0.1	02:54	10:46
	18 Apr	19h 13m 27s	-23° 12′ 27″	Sagittarius	-0.1	02:41	10:35
	26 Apr	19h 30m 45s	-22° 55′ 46″	Sagittarius	-0.3	02:25	10:23
JUPITER	29 Mar	15h 21m 08s	-17° 09′ 04″	Libra	-2.4	23:27	08:40
	04 Apr	15h 19m 29s	-17° 02′ 09″	Libra	-2.4	23:01	08:15
	11 Apr	15h 17m 04s	-16° 52′ 20″	Libra	-2.4	22:30	07:46
	18 Apr	15h 14m 13s	-16° 40′ 53″	Libra	-2.5	21:58	07:17
	26 Apr	15h 10m 33s	-16° 26′ 11″	Libra	-2.5	21:22	06:43
SATURN	29 Mar	18h 37m 03s	-22° 16′ 50″	Sagittarius	0.5	03:17	11:24
	04 Apr	18h 37m 46s	-22° 16′ 05″	Sagittarius	0.5	02:54	11:01
	11 Apr	18h 38m 18s	-22° 15′ 31″	Sagittarius	0.5	02:27	10:34
	18 Apr	18h 38m 28s	-22° 15′ 16″	Sagittarius	0.4	02:00	10:07
	26 Apr	18h 38m 15s	-22° 15′ 25″	Sagittarius	0.4	01:28	09:35

This month's planets

Venus remains the star of the evening skies, while Saturn and Mars keep close company in the morning

Planet of the month



Venus

Constellation: Aries moving into Taurus
Magnitude: -3.9
AM/PM: PM

Venus will return to the sky in April as a beautiful "Evening Star," bright enough to dominate the sky after sunset and draw the eye away from everything else. Not only that, but it will be in a part of the sky rich with star clusters, and will have a spectacular close encounter with the young Moon mid-month.

At the start of April Venus will be relatively low in the west after sunset, but with each day that passes it will climb a little further away from the Sun, improving its visibility until it is setting more than three hours after the Sun. To see Venus at its best you'll want to be somewhere with a clear view to the west, as your viewing won't be cut short by the planet disappearing behind trees, a hill or buildings. It will be immediately obvious to the naked eye, but if you have a telescope it will show you Venus as a bright, gibbous disc.

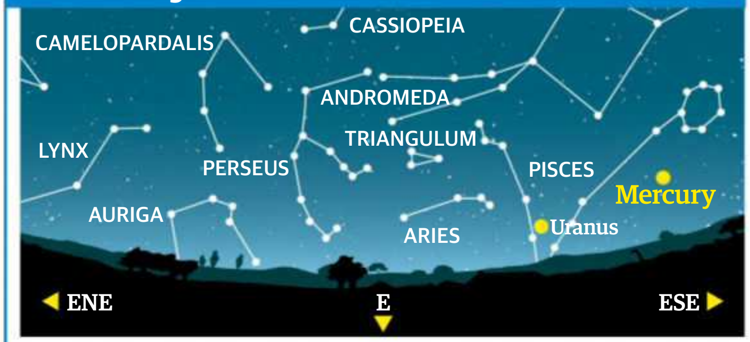
On 17 April, a beautiful, crescent Moon will be shining below and to the left of Venus. By the next evening the Moon will shine to the planet's upper left, and you should see the subtle lavender glow of Earthshine illuminating the dark part of the Moon's disc. After sunset on the 19th the Moon will have climbed further away to Venus' upper left, but they will still be a stunning sight together in the twilight.

In late April Venus will appear to drift up towards, and then pass, the famous Pleiades star cluster. On the evening of 24 April the planet and cluster will be just under three-and-a-half-degrees apart. This celestial fly-by will look particularly pretty through binoculars. Venus will then slide up between the Pleiades and the nearby V-shaped Hyades cluster. Look for Venus shining alongside the Hyades' brightest star, red-hued Aldebaran, on the 27 April.

Venus is often called "Earth's Twin" because it is roughly the same size, but the similarities end there. Earth is an oasis compared to the furnace-hot nightmare world of Venus. Venus is thought of by many planetary scientists as the forgotten planet; although a handful of space probes have been sent there, and other space agencies have studied it, other planets, notably Mars, tend to get more attention paid to them by NASA. Lots of missions to study Venus have been proposed over the years, but none have been approved. This is a great shame, because not only is Venus a fascinating planet in its own right, but studying its climate and weather in the same depth other missions have studied Mars and Saturn would tell us a lot about global warming and atmospheric science, which might help us combat climate change here on Earth.

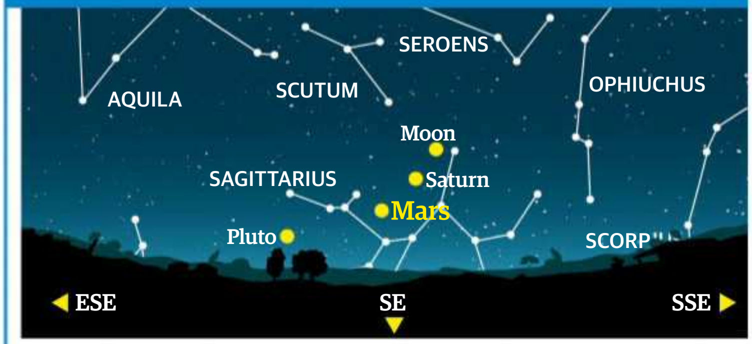
This month's planets

Mercury 07:00 BST on 16 April



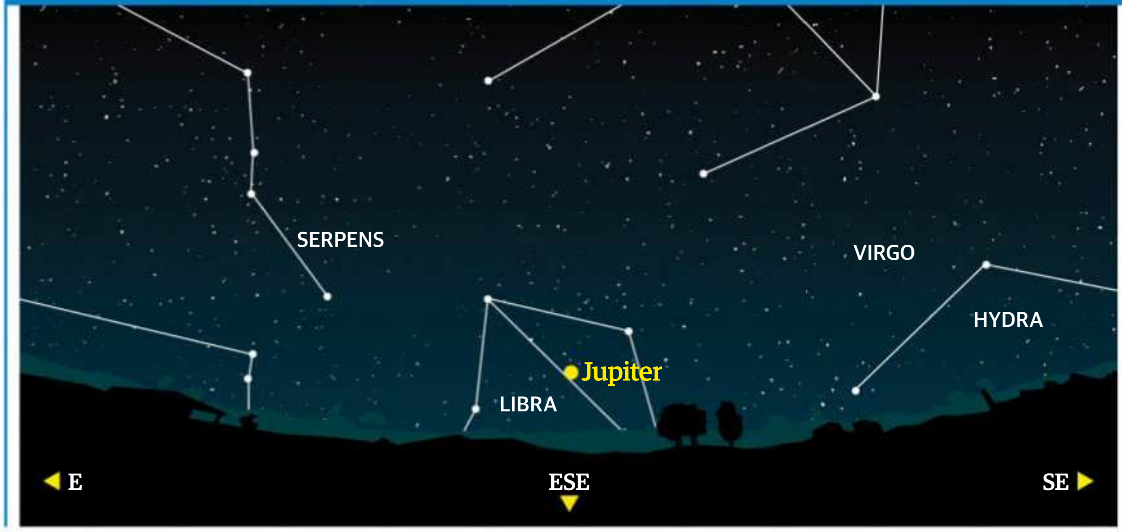
Constellation: Pisces
Magnitude: 1.2
AM/PM: AM
The closest planet to the Sun will be so close to it in the morning sky this month that it will be almost impossible to see. If you are determined to try and find it you'll need to be scanning the eastern sky around half an hour before sunrise, preferably using a pair of binoculars. To prevent injuring your eyes, be sure to stop before sunrise.

Mars 04:00 BST on 07 April



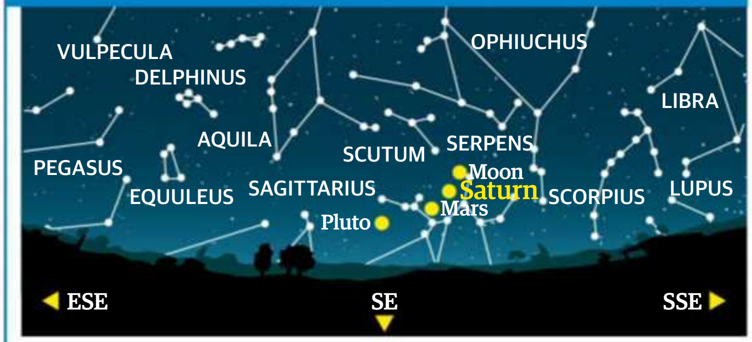
Constellation: Sagittarius
Magnitude: 0.3 brightening to -0.3
AM/PM: AM
Mars will stay low in the sky this month. At the start of the month Mars will be very close to Saturn – just three Moon widths from it before dawn on April Fool's Day – but as the days pass they will move apart. Look for the waning gibbous Moon close to Mars and Saturn before dawn on 7 April, and to their left the next day.

Jupiter 22:00 BST on 24 April



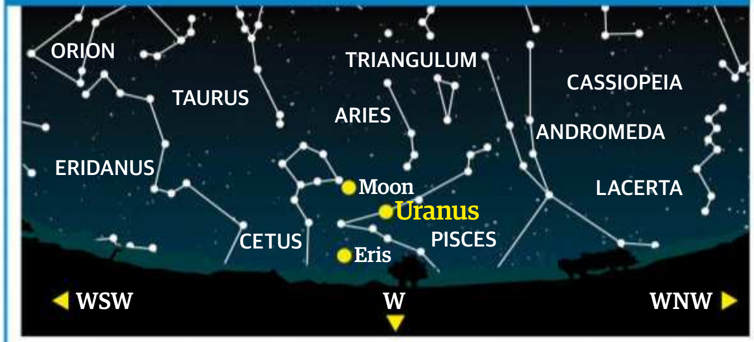
Constellation: Libra
Magnitude: -2.4
AM/PM: AM
The morning sky belongs to Jupiter this month. Strictly speaking the largest planet in the Solar System is an evening object, because at the start of the month it rises before midnight, and by month's end rises before 10pm, but it will be at its best in the early hours. Shining at magnitude -2.4, the planet will easily be the brightest thing in the sky until sunrise. To Jupiter's lower left you'll see the planets Saturn and Mars huddling close together, but neither will come close to Jupiter in terms of brightness or beauty. Look for the Moon shining to Jupiter's upper right on 3 April and to its upper left the next morning.

Saturn 04:00 BST on 07 April



Constellation: Sagittarius
Magnitude: 0.5
AM/PM: AM
Saturn is visible in the morning sky throughout the month, keeping brighter, redder Mars company low above the southern horizon until morning twilight. Make sure to look out for the Moon shining close to Saturn before dawn on the morning of 7 April, when they'll be just over four degrees apart.

Uranus 19:00 BST on 16 April



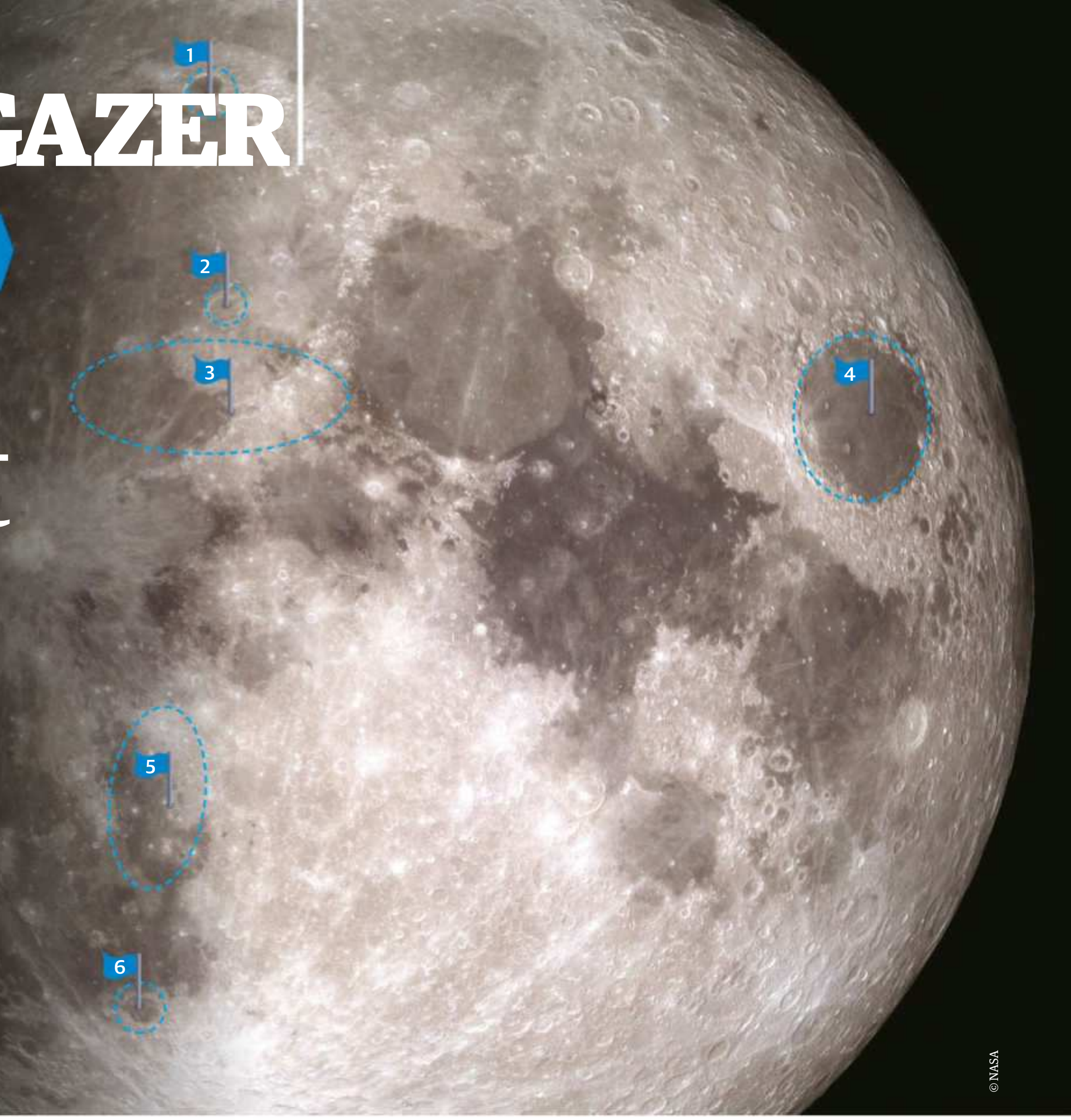
Constellation: Pisces
Magnitude: 5.9
AM/PM: PM
Although Uranus will be above the western horizon after sunset this month, it will not be visible because it will be too close to the Sun. Unlike bright planets such as Venus and Jupiter, Uranus is so faint that its weak light is overwhelmed by a bright background sky, and this month it will be setting barely an hour after the Sun.

STARGAZER

Moon tour

The perfect Moon?

Is there ever a good time to observe our lunar companion? It depends on what you want to see...



© NASA

The different phases of the Moon offer different visual treats and delights. The crescent phase, whether it's a very young 'new' Moon hanging in the western sky after sunset, or an old waning Moon glowing above the eastern horizon before sunrise, is a beautiful sight. It can look particularly striking if it happens to be shining close to a bright planet. If the bright, sunlit crescent is quite thin you can often see the rest of the Earth-facing side of the Moon glowing with the subtle lavender light of Earthshine, too.

Despite what many observers will tell you, the full Moon is not the worst lunar phase to observe. True, with the Sun beating down mercilessly from high above there is no surface relief to see, no shadows are cast behind the Moon's jagged mountains or into the bowls of its deep craters, but the full Moon is when it is easiest to see the contrast between the dark lunar seas and its rugged highlands, and to identify its major features too. Full Moon is also the best time to see the bright 'rays' streaking across the Moon's face – trails of dusty debris sprayed out across the Moon by the impacts which blasted the youngest craters out of the surface. Also, few sights in astronomy can compare with seeing a bloated full Moon rising up from behind the trees like an enormous silvery hot air balloon.

However, I have always thought that one special day of the lunar month offers the best of both worlds, and provides stunning views through binoculars and small telescopes. When the Moon is just slightly gibbous, a day past first quarter – what many people call a 'half Moon' – it offers the observer fantastic views of every type of lunar feature. With the terminator – the line between lunar night and day – running almost straight down the middle of the Moon's face the light is just perfect for seeing its craters, mountain ranges, sprawling seas and long debris rays, too.

Binocular views of the Moon the day after first quarter are fascinating, with the seas on the eastern side of the Moon's face clearly visible as dark, blue-grey splodges, and the largest craters along the terminator looking like pock marks. Through a small telescope with a low-power eyepiece, with the Moon almost filling the eyepiece, you can easily imagine you're a space tourist, flying towards the Moon in a spaceship.

Increase the magnification so you're looking straight down into the craters along the terminator and you'll feel like you're standing behind the astronauts of the future as they descend towards the surface, looking for a safe landing site, just as Armstrong and Aldrin did in 1969 when they guided the Eagle lunar module towards its historic landing on the Sea of Tranquility.

When the Moon has just passed first quarter you will be able to see the sweeping curve of the jagged Appenine mountain range, right on the terminator towards the north. Just above those mountains the crater Archimedes will stand out from the surface in stark relief, looking as fresh as if it had been made the day before. To the east, next to the curving limb, the oval Mare Crisium will look like a dark thumbprint on the Moon, and between it and the terminator other dark seas will form the shape of a crab's claw. In the centre, just to the right of the terminator, a chain of three craters, Ptolemaeus, Alphonsus and Arzachel will look very impressive. At the top of the disc, on the terminator, the dark-floored crater Plato will stand out clearly, while back towards the bottom of the terminator, the young crater Tycho will be starting to emerge from the shadows. As you stare down into it, Tycho might remind you of a bullet hole in a wall, or a pit left on the surface of a frozen lake after the impact of a heavy stone.

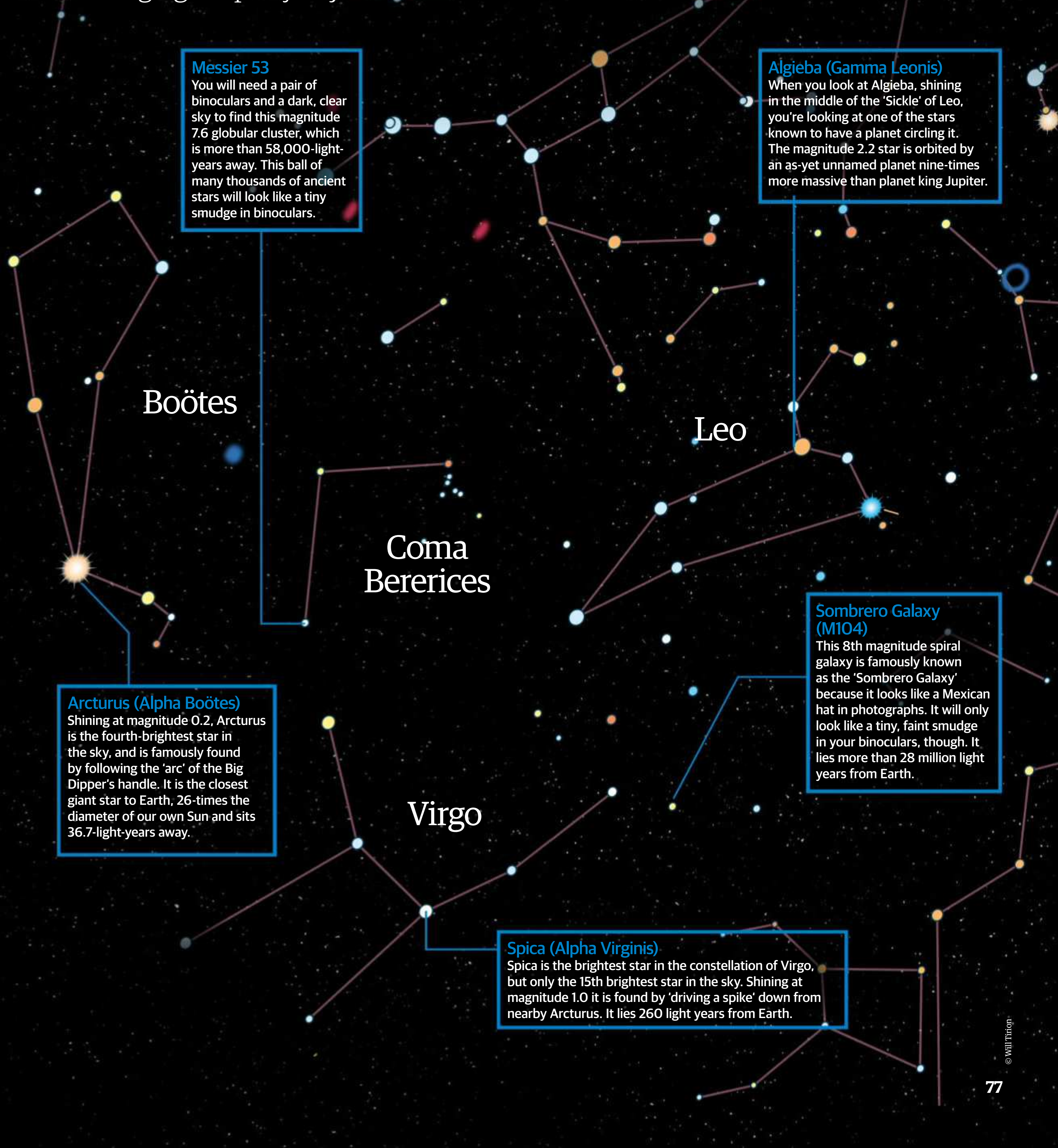
This month the Moon is at first quarter on the evening of 22 April, and if you observe it on that night you will still have fantastic views, but the following night those views will be just a little better. If you don't believe us, take a look yourself!

Key

1. Plato
2. Archimedes
3. Apennine Mountains
4. Mare Crisium
5. Ptolemaeus, Alphonsus, Arzachel
6. Tycho

This month's naked eye targets

The early spring sky offers bright stars and some challenging deep-sky objects...



Messier 53
You will need a pair of binoculars and a dark, clear sky to find this magnitude 7.6 globular cluster, which is more than 58,000-light-years away. This ball of many thousands of ancient stars will look like a tiny smudge in binoculars.

Algieba (Gamma Leonis)
When you look at Algieba, shining in the middle of the 'Sickle' of Leo, you're looking at one of the stars known to have a planet circling it. The magnitude 2.2 star is orbited by an as-yet unnamed planet nine-times more massive than planet king Jupiter.

Arcturus (Alpha Boötes)
Shining at magnitude 0.2, Arcturus is the fourth-brightest star in the sky, and is famously found by following the 'arc' of the Big Dipper's handle. It is the closest giant star to Earth, 26-times the diameter of our own Sun and sits 36.7-light-years away.

Sombrero Galaxy (M104)
This 8th magnitude spiral galaxy is famously known as the 'Sombrero Galaxy' because it looks like a Mexican hat in photographs. It will only look like a tiny, faint smudge in your binoculars, though. It lies more than 28 million light years from Earth.

Spica (Alpha Virginis)
Spica is the brightest star in the constellation of Virgo, but only the 15th brightest star in the sky. Shining at magnitude 1.0 it is found by 'driving a spike' down from nearby Arcturus. It lies 260 light years from Earth.

Spring grand tour

Pack your stargazing bags for an excursion of the wonders of the spring sky...

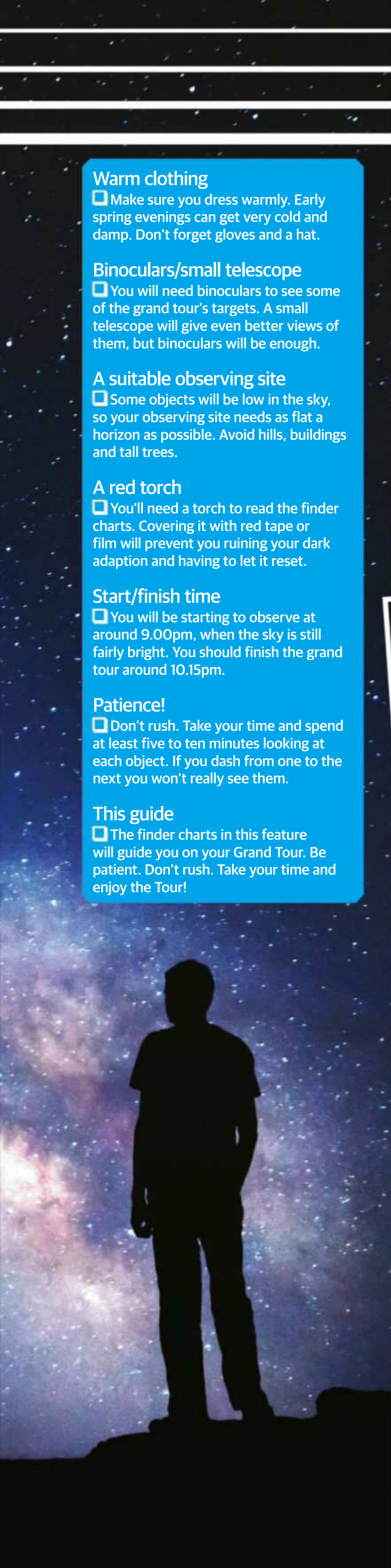
Written by Stuart Atkinson

In the 1970s and 1980s, the Voyager space probes embarked on an ambitious and sweeping 'grand tour' of the outer Solar System. During their tour they swung around and past Jupiter, Saturn, Uranus and finally Neptune, transforming what had been dots in the sky into real worlds. This month we're going to show you how you can go on your own grand tour - not of the worlds that orbit far from the Sun, but of the night sky.

The spring sky offers amateur astronomers and sky watchers a treasure chest of celestial wonders and delights, and many are easy to find. By 'star-hopping' carefully from constellation to constellation, then patiently hopscotching from one star to another, even an inexperienced amateur can track down many different fascinating objects in just a single evening as winter retreats and the spring evenings start to stay lighter for longer.

This feature will be your guide to a grand tour of the spring sky, taking in many different types of astronomical object. It will guide you to a giant, swollen star approaching the end of its life; a beautiful, glowing nebula where stars are being born; a glittering open star cluster; a misty globular star cluster; the ghostly remains of a long-dead star and even a star with an exoplanet known to be circling it.

Although many of the objects featured in our grand tour are visible to the naked eye, you will need some extra help with some, so you'll need a pair of binoculars or small telescope if you're going to see everything on the tour itinerary.



Warm clothing
☐ Make sure you dress warmly. Early spring evenings can get very cold and damp. Don't forget gloves and a hat.

Binoculars/small telescope
☐ You will need binoculars to see some of the grand tour's targets. A small telescope will give even better views of them, but binoculars will be enough.

A suitable observing site
☐ Some objects will be low in the sky, so your observing site needs as flat a horizon as possible. Avoid hills, buildings and tall trees.

A red torch
☐ You'll need a torch to read the finder charts. Covering it with red tape or film will prevent you ruining your dark adaption and having to let it reset.

Start/finish time
☐ You will be starting to observe at around 9.00pm, when the sky is still fairly bright. You should finish the grand tour around 10.15pm.

Patience!
☐ Don't rush. Take your time and spend at least five to ten minutes looking at each object. If you dash from one to the next you won't really see them.

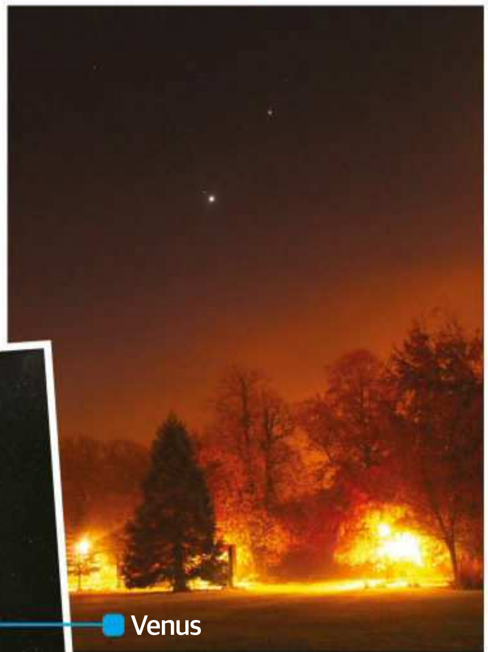
This guide
☐ The finder charts in this feature will guide you on your Grand Tour. Be patient. Don't rush. Take your time and enjoy the Tour!

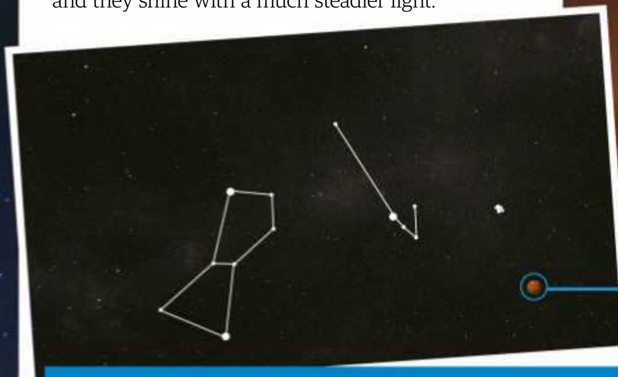
Let the tour begin!

Time to begin your journey of the spring sky – have fun and take your time with each target

1 VENUS *Earth's 'evil twin'*

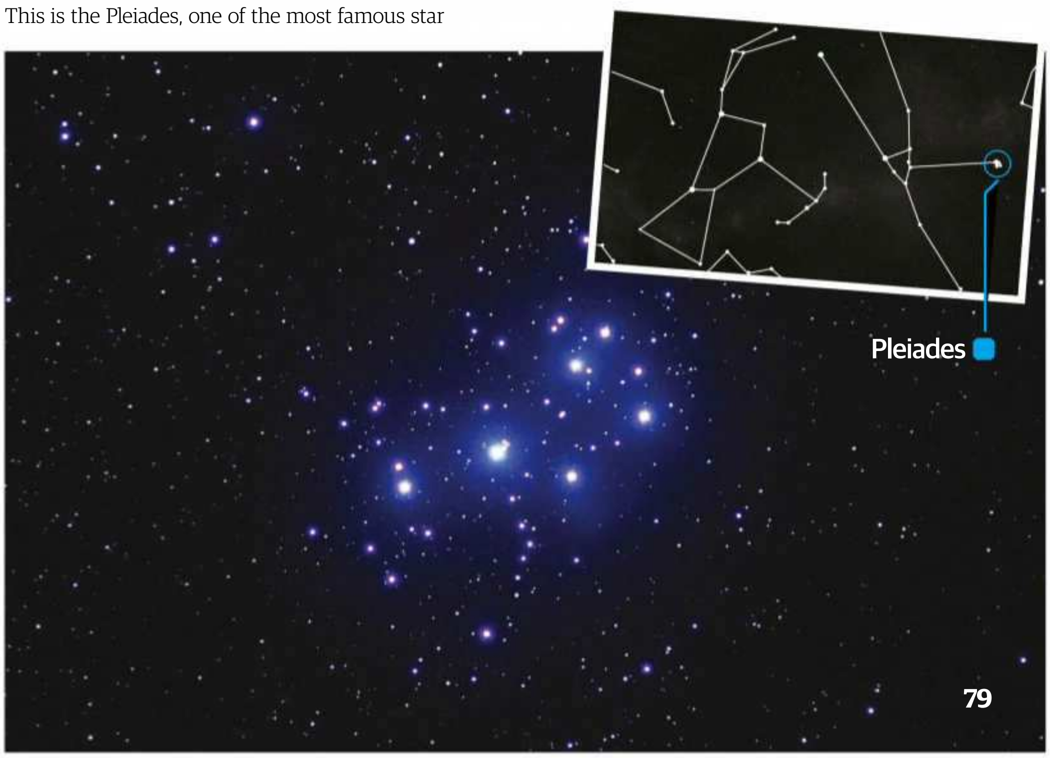
We begin with the brightest thing in the night sky: Venus. Right now Venus is a beautiful 'Evening Star'. To find it, just look towards the west as the sky darkens and Venus will be a gorgeous blue-white spark of light above the horizon. At magnitude -3.9 Venus is so bright it pierces the twilight glow long before any of the stars, and as dusk deepens it only gets more and more beautiful. Looking at Venus you'll notice how it's not twinkling. This is because planets are tiny discs in the sky rather than points of light like the stars, so their light is broken up less and they shine with a much steadier light.





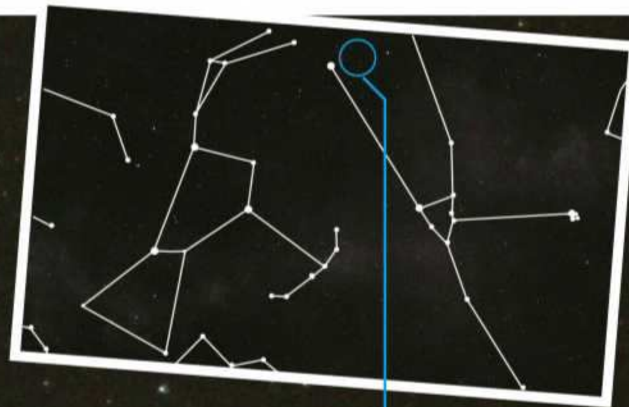
2 THE PLEIADES (M45) *A beautiful cluster of stars*

After a half-hour break back inside to warm up and let the sky darken a little, go out again and return to Venus. Looking a short distance to the upper left of the planet you'll see a tiny knot of stars, about the size of your thumbnail, held out at arm's length. This is the Pleiades, one of the most famous star clusters in the sky. It is nicknamed 'The Seven Sisters' because people with good eyesight can see its seven brightest stars with their naked eye. If you can't, don't worry, just use your binoculars and you'll see several dozen icy-blue stars in the cluster.



3 CRAB NEBULA (M1)
The remains of a dead star

You've had it easy so far, so time for a challenge! Find the V-shaped Hyades star cluster to the left of the Pleiades and follow a line up from its left-hand side to a third-magnitude star a short distance away. Centre that star in your binoculars and you'll see what looks like a tiny out-of-focus star to its lower right. This is M1, the Crab Nebula, the remains of a star that was observed to blow up in a massive supernova explosion in 1054, but actually died more than 6,000 years earlier. At magnitude 8.4 it is easily the faintest object on the tour, so don't worry if you don't find it first go!



4 BETELGEUSE
A red supergiant star

Look down to the lower left of the Crab Nebula and you'll spot a bright orange-red star. This is Betelgeuse in the constellation of Orion, and at magnitude 0.45 it is the ninth-brightest star in the sky. 500 light years from Earth, Betelgeuse is a red supergiant star 650-times wider than our own star; if it was put in the Sun's place it would swallow up the orbit of Mars! To your eye Betelgeuse will be a rich orange colour, but binoculars will really enhance its gorgeous, smoky-amber hue.

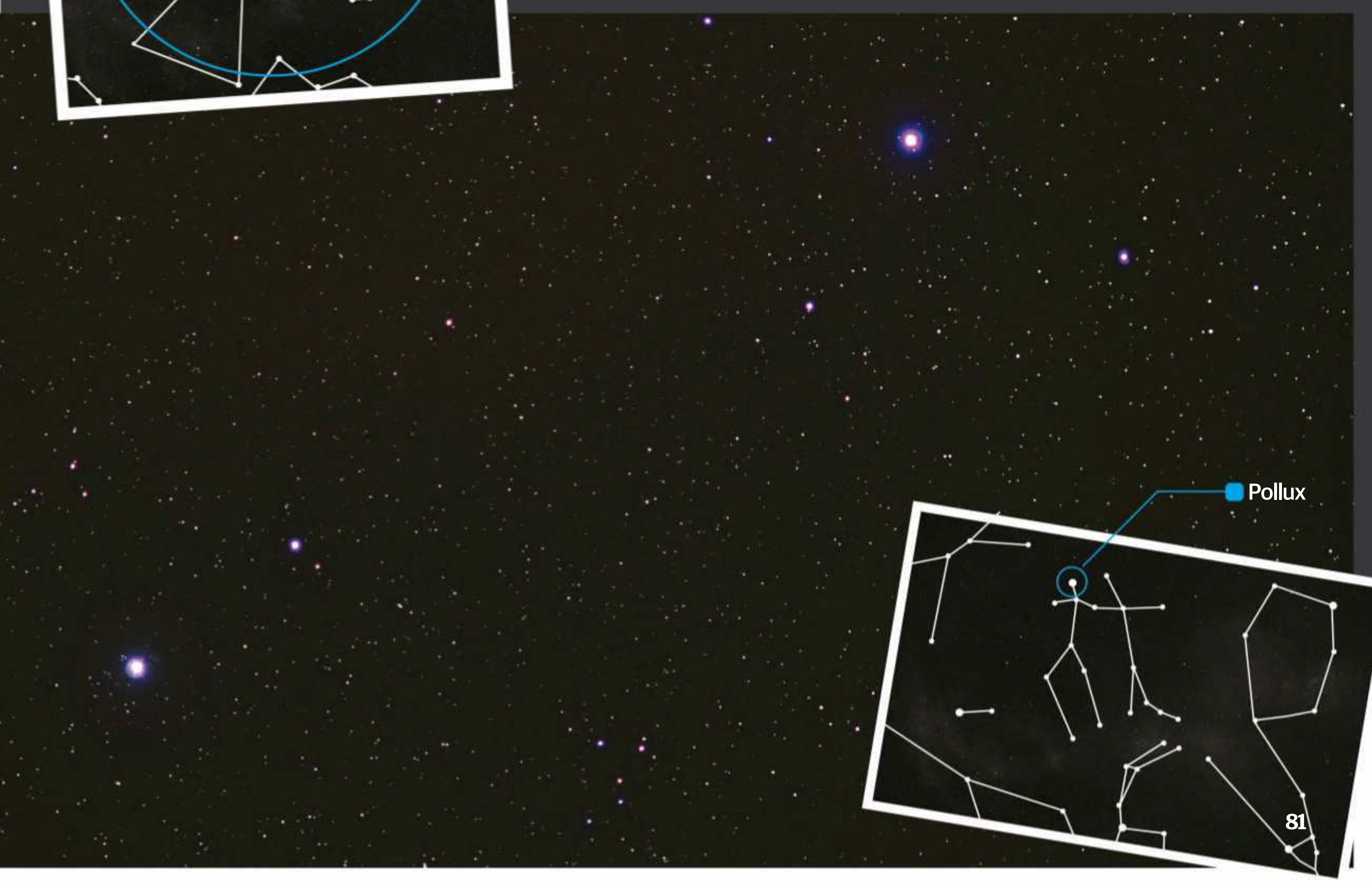
6 POLLUX
A naked-eye star with an exoplanet

Go back to orange Betelgeuse and continue straight up past it until you come to a close pair of stars. The first-magnitude star on the left, slightly lower than the other, is Pollux, brightest star in Gemini. Pollux is a cool orange-yellow giant and it's on our tour because it is one of the few naked-eye stars we know to be orbited by an exoplanet, a planet beyond our own Solar System. The planet has been christened Thestias and it orbits Pollux once every 589 days. Look at Pollux through your binoculars and imagine that alien world whirling around it…

5 ORION NEBULA (M42)

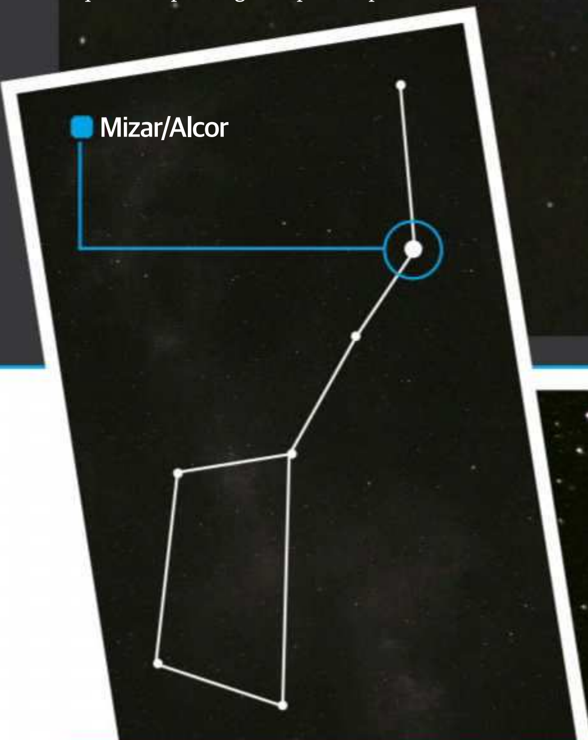
A stellar nursery

Drop down from Betelgeuse to the famous Orion's Belt, a horizontal line of three blue stars, then go a little further to Orion's Sword, a much shorter vertical line of three stars. To your naked eye the middle star will look fuzzy and blurry, because it's not a star but a nebula, a huge cloud of glowing gas and dust. Your binoculars will show the soft blue-grey haze of the nebula, and a small telescope will reveal subtle wisps, swirls and curls within it. The nebula is over 1,400-light-years away and is a stellar nursery where stars are being born.



7 MIZAR AND ALCOR
A beautiful double star

Next you need to turn your back on everything you've looked at so far, so you're facing the east. Look up high in the sky and find the familiar shape of the Big Dipper, or the Plough. Our next stop is Mizar, the second-magnitude star in the middle of the Dipper's handle. If you have good eyesight you'll see that there is another tiny, faint star very close to Mizar, Alcor, and these two distant suns form probably the most famous double star in the sky. Use your binoculars if your eyesight isn't quite sharp enough to split the pair.

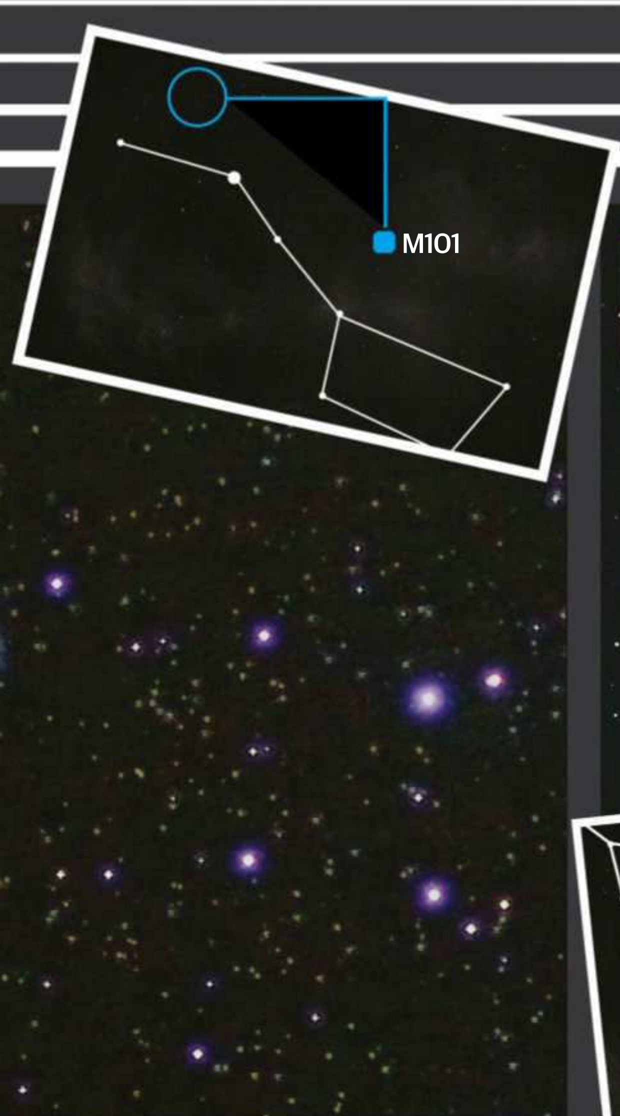


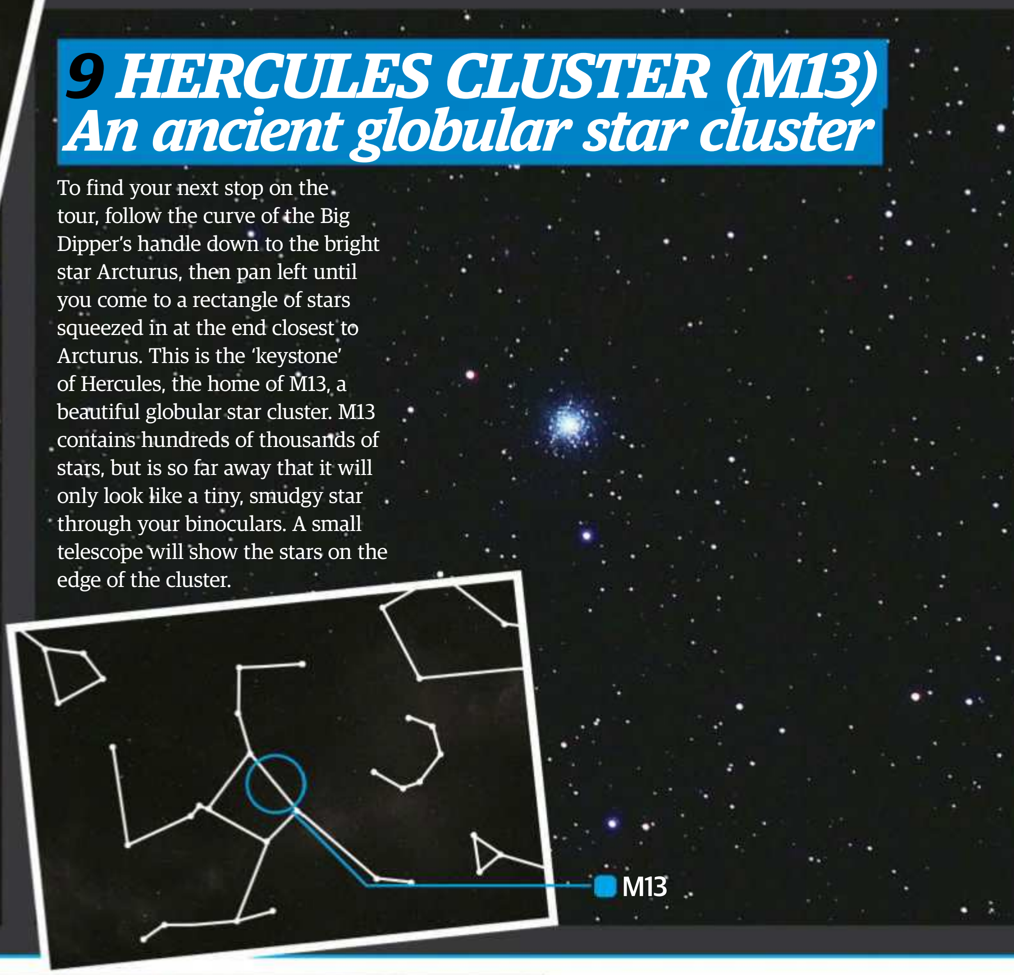
8 PINWHEEL GALAXY (M101)
A spiral galaxy

The second-faintest object on our grand tour is a spiral galaxy. At magnitude 7.9, M101 is far too faint for your naked eye to see, even in the darkest sky, but your binoculars will pick it out as a tiny circular smudge to the lower left of Mizar and Alcor. M101 is known as the 'Pinwheel Galaxy' because of its beautiful shape in photographs, but don't worry about not seeing any detail when you look at it; just be amazed to be gazing at another galaxy 23-million-light-years away...

10 THE DOUBLE CLUSTER (NGC 869 & NGC 884)

Complete your grand tour by leaving Hercules, angling down and left to the bright star Vega, then sweeping your gaze further to the left until you reach the 'W' of Cassiopeia. Directly between it and the neighbouring wishbone of Perseus your naked eyes will pick up a smudgy blur. Through your binoculars you'll see that blur is not one but two small clusters of pinprick blue stars almost touching each other, looking like tiny piles of salt on black paper. This is the Double Cluster, but the two clusters are not physically related, one is much further away than the other. They just lie in the same direction as seen from Earth.

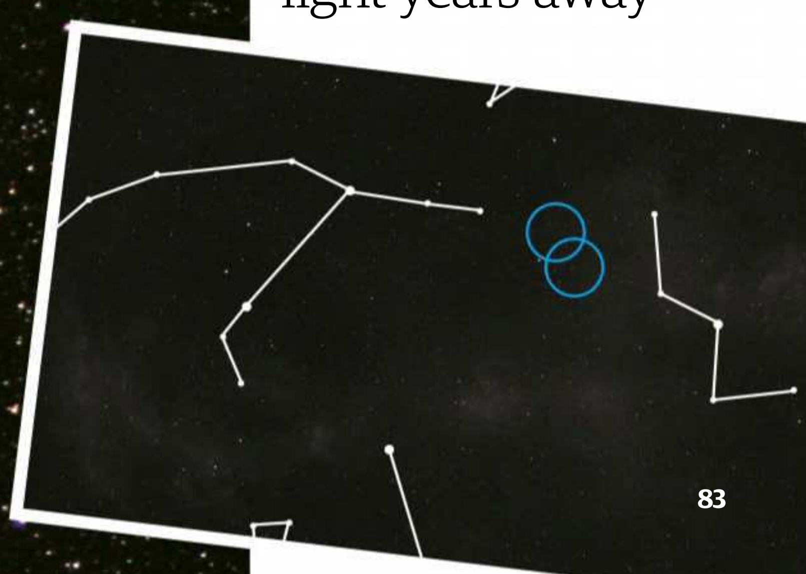




9 HERCULES CLUSTER (M13)
An ancient globular star cluster

To find your next stop on the tour, follow the curve of the Big Dipper's handle down to the bright star Arcturus, then pan left until you come to a rectangle of stars squeezed in at the end closest to Arcturus. This is the 'keystone' of Hercules, the home of M13, a beautiful globular star cluster. M13 contains hundreds of thousands of stars, but is so far away that it will only look like a tiny, smudgy star through your binoculars. A small telescope will show the stars on the edge of the cluster.

"Don't worry about not seeing any detail when you look at it; just be amazed to be gazing at another galaxy 23-million-light-years away"



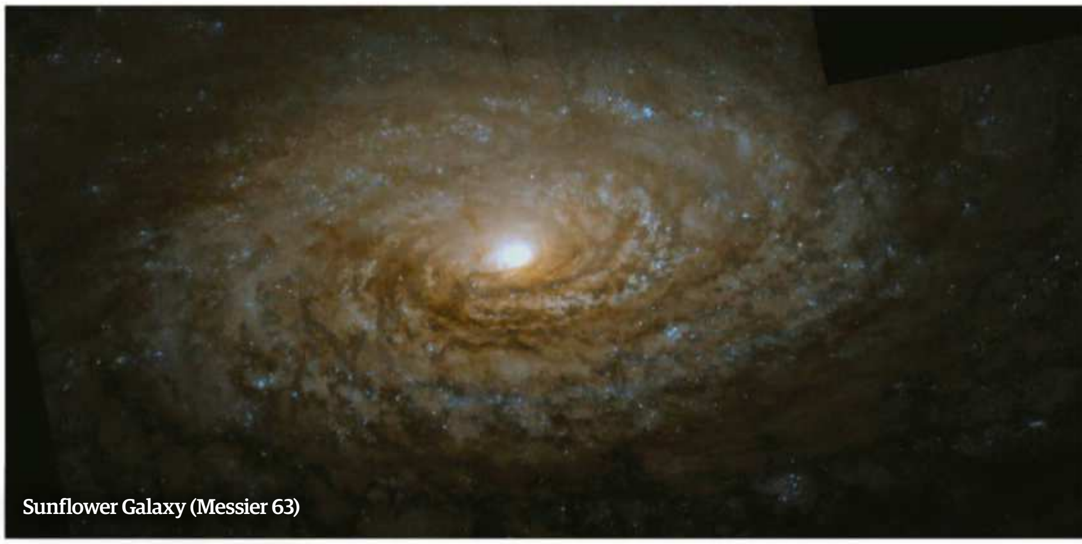
Messier 106

Deep sky challenge

Seek the Hunting Dog and the Great Bear's night-sky jewels

Spring has arrived, and with it a wealth of deep sky objects on which to turn your telescope

For those of us in the Northern Hemisphere, high overhead on spring nights can be found the constellations of Canes Venatici (the Hunting Dogs) and Ursa Major (the Great Bear). Both contain several bright distant galaxies along with many fainter ones, as well as an interesting nebula. Possibly the most famous of all the double stars, which is in fact a multiple star system, lies in this region too. There are some well-known galaxies that will be relatively easy target for even small telescopes but many will require a larger aperture and dark skies to see well.



Sunflower Galaxy (Messier 63)

1 The Whirlpool Galaxy (Messier 51)
Use the tip of the Great Bear's tail to find this interacting galaxy. You'll need at least a small telescope to pick out a diffuse patch of light with a bright central region at its heart.

2 Pinwheel Galaxy (Messier 101)
Scopes with an aperture of about three inches will reveal a nebulous haze with a bright centre, while an eight-inch instrument will show a bright, condensed core surrounded by nebulosity.

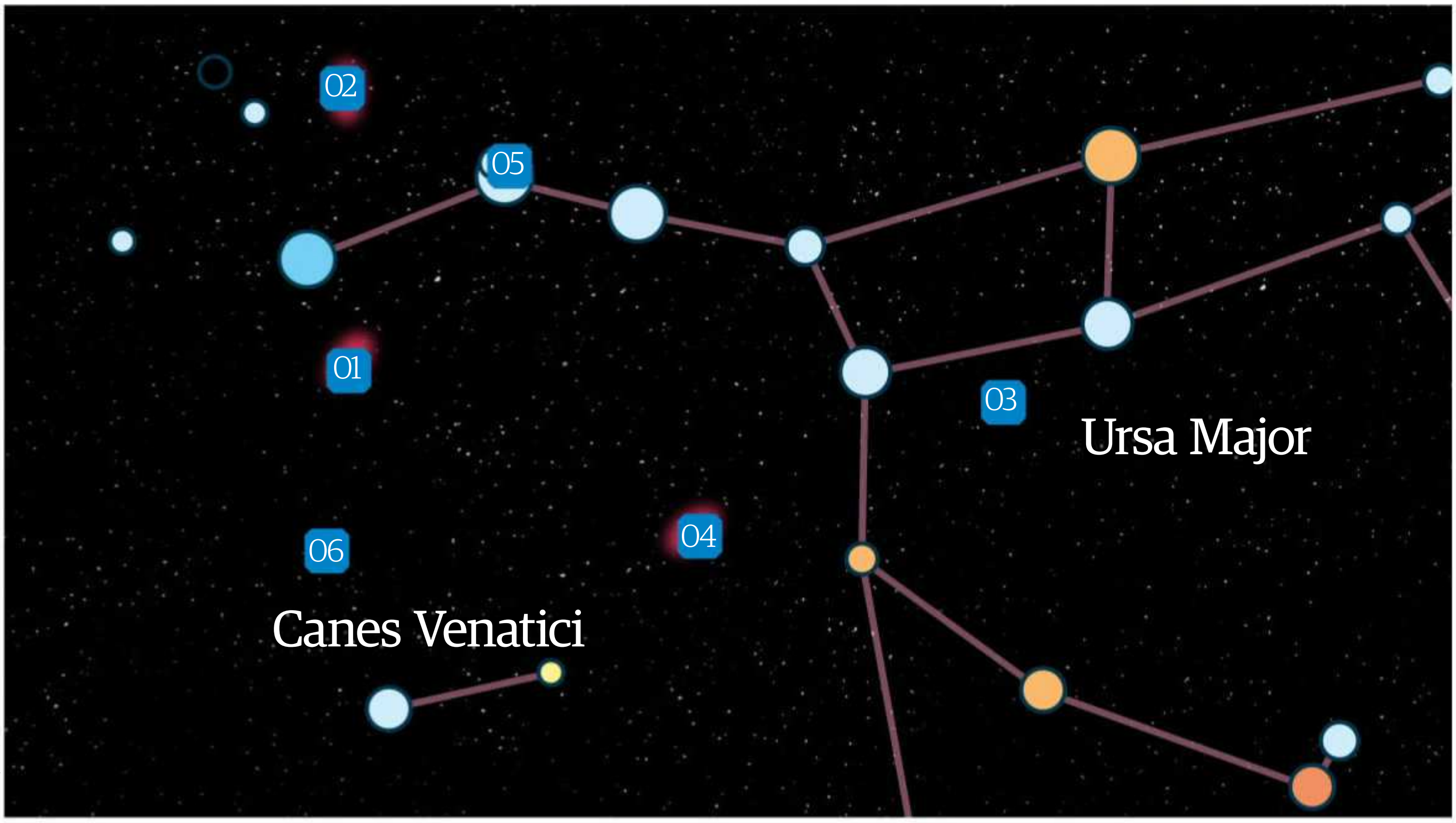
3 The Owl Nebula (Messier 97)
This is a planetary nebula - a star, which has shed its outer shell of gas. Larger telescopes will show two dark patches that give this deep-sky object its appearance.

4 Messier 106
Spiral galaxy Messier 106 can be picked up with binoculars, while small telescopes show a diffuse patch with a bright centre. An eight-inch instrument will reveal details of the structure.

5 Mizar and Alcor
The widest of the naked-eye double stars. Through the field of view, the stellar duo twinkle as a pair of white-blue jewels, where Alcor is the faintest of the pairing at a magnitude of 4.

6 Sunflower Galaxy (Messier 63)
One of the prettiest spiral galaxies in the night sky. A large telescope with medium power shows it well. With the right aperture, usually ten inches or more, you'll can pick out the dust lanes.


Pinwheel Galaxy (Messier 101)



How to...

Get started in spectroscopy

Splitting light up into its constituent colours, or spectrum, can tell us a lot about what the light from an astronomical object is made of. Here's how to make a simple Do It Yourself spectroscope...

You'll need:

- ✔ Cereal box
- ✔ Old CD disc
- ✔ Sticky tape
- ✔ Modelling knife

As you may know, light can be broken up into the colours of the rainbow, known as a spectrum. This can be done at home using the properties of an old CD to break up the light. The spectrum will show you light and dark lines, which can also tell you what the sunlight, or other light source, is made up from.

Astronomers use similar devices, although somewhat more sophisticated, in their studies of the stars. The CD acts as a diffraction grating, that is, the circular tracks on the CD are so close together that they split up the light and spread each different wavelength to a differing position; this is the spectrum.

This spectrum is spread perpendicular to the CD - this is why the slit and the viewing holes need to be at 90° to each other. Each colour bends at a particular angle. For you to see the spectrum, the light must diffract off the CD and reflect into your eye. Adjusting the tilt of the CD allows you to properly bounce the spectrum into your eye.

The quality of the spectrum you get depends on how well you make the spectrometer. The slit which lets the light into the box needs to be thin, but not too thin, otherwise the image will be too dark. Conversely, if the slit is too wide, the spectrum lines will appear to be blurred.

If done right it is easy to use and a great way of getting into spectroscopy. It's a great tool for children, too, and is perfectly safe to use. You can also take pictures of the various spectra that you can see. This makes it easier to compare different kinds of light.

It's easy to make, although care should be taken, as you would using any sharp tool, when cutting the slit. You can use the spectrometer to examine light from other sources too, such as tungsten lights, strip lights and even the Moon. If you have a telescope, you could try using it on a bright star by holding the device over the eyepiece. You'll be able to spot the bright lines in the spectrum corresponding to various chemical elements in the light source. See what you can discover.

> "The quality of the spectrum you get depends on how well you make the spectrometer"

Tips & tricks

Choose the right box
You can use a cereal box, cardboard tube or similar to make the spectroscope.

Craft a slot
Make sure the slot you cut is no more than 2mm wide and free from debris.

Ensure the CD fits
The hole for the CD needs to be about 3/4 of the width of the CD.

Strengthen the box
Use sticky tape to strengthen the box if it needs it, especially around the hole for the CD.

Mark out a suitable angle
The angle of the CD needs to be 60°, use a protractor to mark this.

Read between the lines
You can use the spectrometer on many differing light sources and it will show the spectra as bright and dark lines.

How to make your own spectrometer

Start with the Sun, then compare different spectra

Use the spectrometer to see the differences between various light sources for yourself. The Sun is the easiest one to start with and you'll see the rainbow spectrum displayed in all its glory. The light and dark lines show the various chemical elements present in the light source, such a sodium, calcium and so on. You can try it on the Moon and other light sources, too, and spot any differences.

Send your photos to
space@spaceanswers.com

1 Get a suitable box

Use an old cereal box or similar and cut a viewing hole to be about 3/4 of the width of the CD.

2 Cut out the slot

Craft a slot at the other end of the box not more than 2 millimetres wide and at 90° to the viewing hole.

3 Craft the CD-holder slot

Engineer a slot at the viewing hole at 60° to accommodate the CD, use a protractor to be as accurate as possible.

4 Strengthen with tape

Use sticky tape to reinforce the box if necessary, especially around the end in which you view the action.

5 Go for an unscratched CD

Use an unscratched CD for the best possible results and place it into the slot you've cut out at the viewing-hole end.

6 Select your target

Allow sunlight or light from a strip light, or any other light source for that matter, to enter the narrow slot and enjoy the results!

STARGAZER

The Northern Hemisphere

Some bright stars of winter still linger after sunset, but spring lets you look out of the plane of the Milky Way

Bright yellow-white star Capella of Auriga (the Charioteer) sits low in the north-western sky this month, a striking sight at magnitude 0.08 alongside easy-to-locate Gemini's (the Twins) Castor and Pollux.

Ursa Major's 'Big Dipper' is the easiest asterism to find as soon as darkness falls, making it easy to use its pointer stars to find Polaris. Follow the pointers in the other direction and you will find bright-white star Regulus in Leo (the Lion), and trace your finger along the bowl and you'll find yourself led to brilliant yellow-orange star Arcturus in the constellation of Boötes (the Herdsman). Nearby, just north-east of Arcturus, you'll be greeted by the unmistakable semi-circle of the Northern Crown, Corona Borealis.

Using the sky chart

This chart is for use at 10pm (BST) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

Magnitudes

- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

- O-B
- A
- F
- G
- K
- M

Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies

Observer's note:
The night sky as it appears on 15 April 2018 at approximately 10pm (BST).


The Flaming Star Nebula (IC 405)


Capella in the constellation of Auriga


Messier 88

Astroshots of the month

Send your astrophotography images to **space@spaceanswers.com** for a chance to see them featured in **All About Space**

Nigel Gilchrist

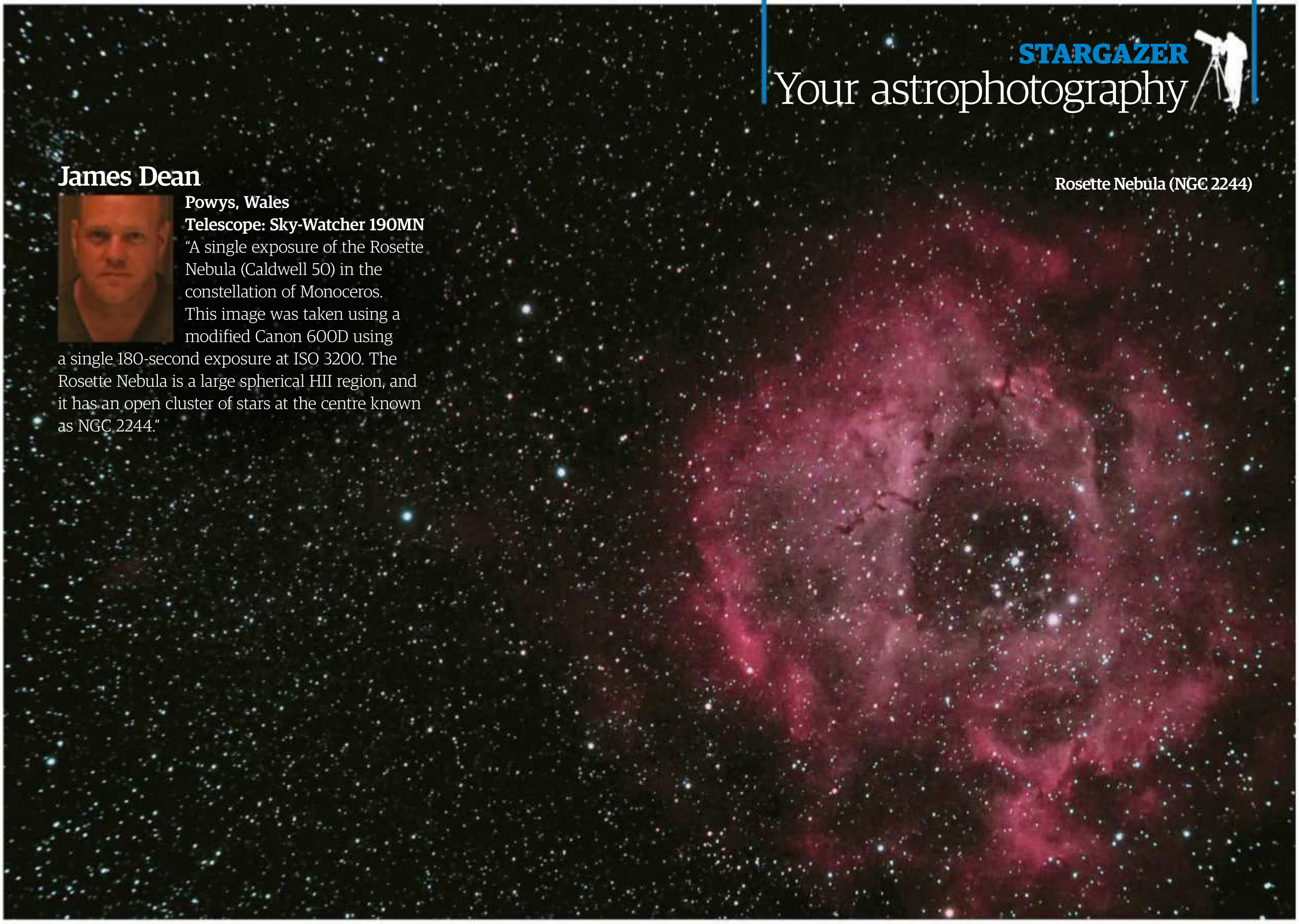
Rayleigh, Essex
Telescope: Equinox 80ED Pro

"I have been imaging the deep sky for two years after a lifetime of not knowing it's possible to capture amazing images from a back garden with small telescopes and a DSLR. I immediately got hooked on astrophotography and can see the hobby lasting a long time. Starting with basic equipment, the steady improvements are a joy to see; each image is a bit better than the last and a bit more knowledge is gained. Now I'm saving up for a better camera and bigger mount to take it to the next level."

Andromeda Galaxy (M31)

Rosette Nebula (NGC 2244)

Orion Nebula (M42)

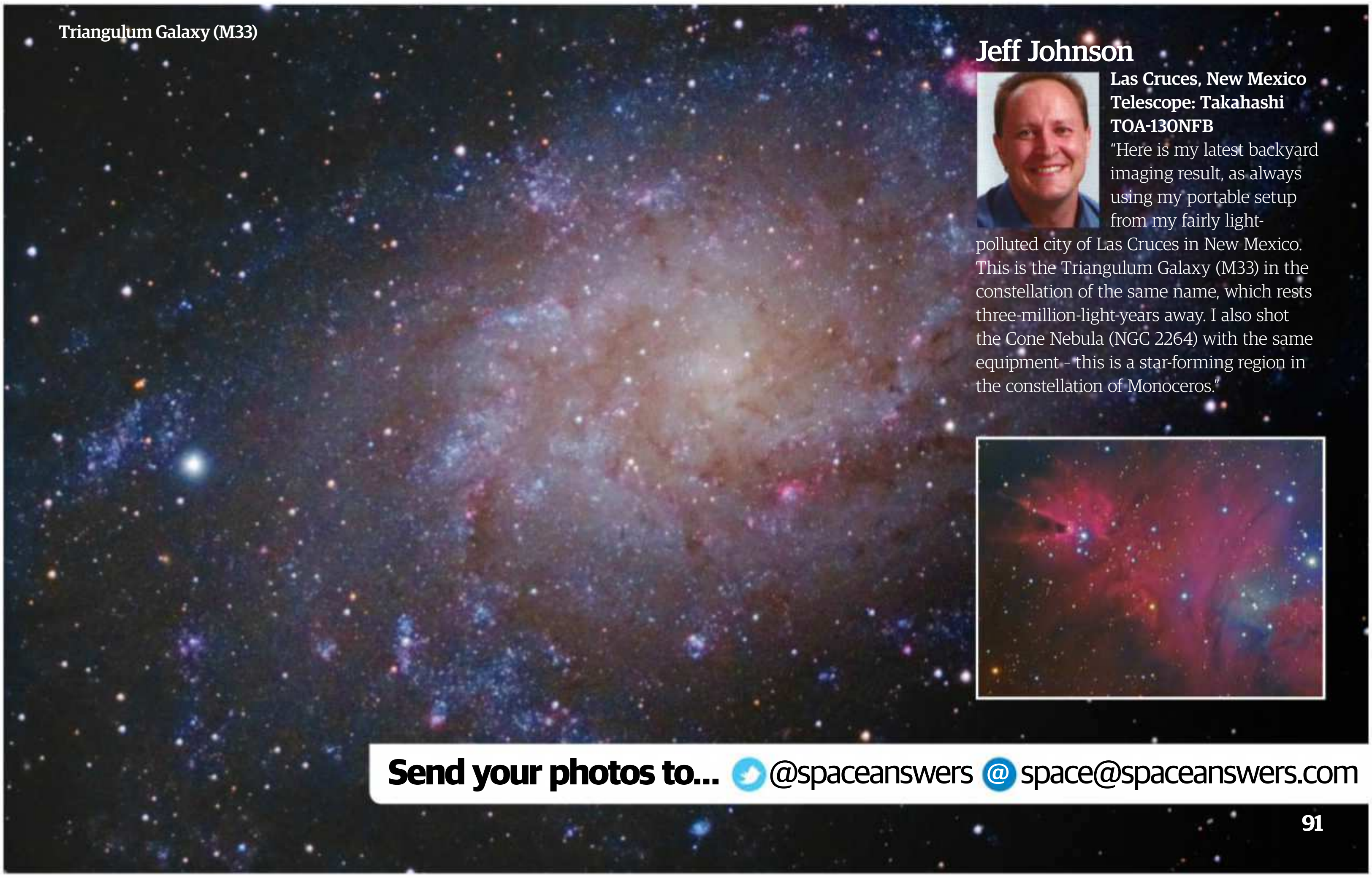


Rosette Nebula (NGC 2244)

James Dean

Powys, Wales
Telescope: Sky-Watcher 190MN

"A single exposure of the Rosette Nebula (Caldwell 50) in the constellation of Monoceros. This image was taken using a modified Canon 600D using a single 180-second exposure at ISO 3200. The Rosette Nebula is a large spherical HII region, and it has an open cluster of stars at the centre known as NGC 2244."



Triangulum Galaxy (M33)

Jeff Johnson

Las Cruces, New Mexico
Telescope: Takahashi TOA-130NFB

"Here is my latest backyard imaging result, as always using my portable setup from my fairly light-polluted city of Las Cruces in New Mexico. This is the Triangulum Galaxy (M33) in the constellation of the same name, which rests three-million-light-years away. I also shot the Cone Nebula (NGC 2264) with the same equipment – this is a star-forming region in the constellation of Monoceros."

Send your photos to... @spaceanswers space@spaceanswers.com

Vixen VMC110L

Good things come in small packages, and this Maksutov-Cassegrain is a testament to that exactly

Telescope advice

Cost: £395 (approx $542.60)
From: Opticron
Type: Maksutov-Cassegrain
Aperture: 4.33"
Focal length: 40.75"

Best for...

- Beginners
- Medium budget
- Planetary viewing
- Lunar viewing
- Bright deep-sky objects
- Basic astrophotography

We had a very positive and enjoyable experience with Vixen's portable Maksutov-Cassegrain telescope, and based on its build and optics, we would strongly recommend this telescope to a beginner. You can also utilise its unique flip mirror to get stuck into some astro imaging.

Let's begin with what comes with the package. The minor, but still essential accessories include the red dot finder and the mount rail. The red dot finder is of very good quality and easy to attach, and the mount rail is of a dovetail design, meaning it will be compatible with most mounts. The VMC110L itself, with VMC meaning 'Vixen's original Maksutov-Cassegrain', is superb. Its design optimises its impressive aperture and focal length to create a generous light-capturing capability. The telescope's size is the first thing that catches the eye, as it is relatively tiny. The Cassegrain aspect of the design allows a long focal length in a short tube of only 360 millimetres (14 inches). When you unite this with the fact that the telescope weighs only 2.1 kilograms (4.6 pounds), it makes for a perfect transportable, grab-and-go telescope.

With its sturdy metal construction it will be sure to survive a few bumps and knocks on its travels.

Its open-tube design is great to avoid overheating, as it will allow the cool fresh air to circumvent throughout the equipment. However, this does require more attention for the cleanliness of the mirror, as it will be more vulnerable to dirt and dust. An incredibly unique feature on this telescope is the ability to flip the mirror focus between the back plate and a 90-degree eyepiece on the side of the tube. This allows the user to switch effortlessly between astrophotography and observation.

In order to use the telescope for astrophotography, all that needs to be attached is a 42-millimetre (1.7-inch) T-ring to the back plate, and you should be ready to go. Based on the specifications alone, we would recommend this telescope for photographing very bright objects. Given the aperture and focal length of the telescope, this provides a respectable focal ratio of f/9.4. This is best suited for observing the brighter celestial objects, including some of the more flamboyant deep-sky objects. This sort of target is ideally suited for an astronomer who is learning the ropes. If you wanted to try and tackle harder targets with a lower magnitude, a telescope with a lower focal ratio would be better suited.

When the Vixen spyglass got put to the test the sights were fantastic, especially given the price and capabilities of the telescope. We attached the telescope to a Porta II alt-azimuth mount and had a 25mm (one inch) Plössl eyepiece at hand in order to see what we could find. Given that the telescope has a light-gathering power of 247x, the 25-millimetre eyepiece gave us a magnification of 41x. To kickstart the observing session, we aimed for the biggest target in the sky, the Moon. The Moon shone brightly with 87 per cent luminosity and a face full of craters and mares, and the VMC110L showed these in much clarity.

Next we turned to the double star in an ever-present constellation in the Northern Hemisphere, Ursa Major,


Being small and light, the VMC110L is ideal for a grab-and-go telescope

The flip mirror allows the choice of two focal points

"The sights were fantastic, especially given the price and capabilities of the telescope"

known as Mizar and Alcor. These stars, shining with magnitudes of 2.2 and 3.95 respectively, were shining clearly and there appeared to be no aberration. To test out another star we turned to the second-brightest star in the sky behind the Sun, Sirius. The optics rendered a star flickering with a variety of colours, which was a very enjoyable sight.

Before the Andromeda Galaxy (M31) disappeared below the horizon, we decided to get a quick look at it while it was located around the 30-degree azimuth latitude. The central concentration of light was extremely noticeable when it was located in the field of view, and we even caught a slight sight of the dark dust trails.

Using the aforementioned feature, the flip mirror, you can get some amazing images of these objects while being able to change between observing it though an eyepiece and photographing it. One issue with this flip mirror is the collimation. Although it did not happen with our review model, if the telescope were to become out of focus, the fact you can have two focal points would cause an issue. In the manual they recommend contacting your nearest Vixen dealer if that were to occur.

Overall, the Vixen VMC110L ticks all the boxes for a beginner's telescope. It's easy to transport, it has great optics that produce clear views and if you fancy a new challenge, you can use it for a bit of astrophotography. The flip mirror feature is a great feature to have, and we have not seen it on many other telescopes. Obviously, you would still need to purchase a tripod and mount to harness the full potential of this telescope, but a simple alt-azimuth mount should do the trick, and its dovetail mounting joint should be compatible with most mounts. Using an equatorial mount would be ideal for tracking the motion of the stars as they move across the night sky, but that's not essential unless you are doing long exposure times, which this telescope is not really best suited for.

The telescope is a modified Maksutov-Cassegrain with great light-capturing capabilities

WIN!

SKY-WATCHER SKYMAX-102 (AZ-EQ AVANT)

Capitalise on a scope with the latest in mount technology, providing both alt-azimuth and equatorial movement

WORTH £315

An astronomer's greatest hindrance can be the clouds, and sometimes its just best to sit by the window and wait for them to disappear. When your window of opportunity arises, allowing you to check out some celestial gems you've been waiting to see sparkle, you need a telescope you can just grab and go.

This makes the Sky-Watcher Skymax-102 with its brand-new AZ-EQ AVANT mount the ideal telescope. Sky-Watcher has combined their incredibly popular Skymax-102 Maksutov-Cassegrain with the latest in mount technology, which allows for both equatorial and alt-azimuth movement of the telescope.

Promoting simple operation, the alt-azimuth will allow you to quickly navigate the heavens with ease. Meanwhile the equatorial function will provide the user with the opportunity to track the motion of the night sky, springing a new platform for astronomers wanting to delve into astrophotography. The Skymax-102 telescope is a fantastic piece of equipment for all levels of observer, providing crisp and clear images of the brightest objects in the night sky.

Sky-Watcher®
Be amazed.

OVL

To be in with a chance of winning, all you have to do is answer this question:

How many deep sky objects make up the 'Messier Catalogue'?

A: 99 B: 110 C: 125

Enter via email at
space@spaceanswers.com or by post to
All About Space competitions, Richmond House, 33 Richmond Hill, Bournemouth, BH2 6EZ

Visit the website for full terms and conditions at **www.spaceanswers.com/competitions**

Congratulations to Anthony Cameron, who is the winner of the Altair Astro GPCAM2 290C colour camera

In the shops

The latest books, apps, software, tech and accessories for space and astronomy fans alike

1 Book **Astroquizzical: A Curious Journey Through Our Cosmic Family Tree**

Cost: £16.99 (approx. $23.61) **From:** Icon Books Ltd

Astroquizzical: A Curious Journey Through Our Cosmic Family Tree approaches astronomy at a unique angle. It begins by stating that we are all distantly related to the stars; everything we're made of can be traced back to when they explode. By making this comparison at the start of the book, you instantly become intrigued and involved and from then on, the author - Jillian Scudder - does a fine job of covering a variety of topics and interests in space science.

The book starts at our home planet and the universe expands as the story unfolds, explaining the intricacies of our Solar System, the variety and evolution of stars, galaxies and finally the broader universe. These areas are well explained and accompanied by a series of illustrations, thought experiments and images. This is a welcome element to the book, particularly when it comes to explaining difficult concepts such as the behaviour of particles travelling at the speed of light and other more in depth, complicated topics.

2 Program **Project Discovery**

Cost: Free **From:** www.eveonline.com/discovery

Project Discovery is a citizen science mini-game which is part of a much more extensive online role-playing game called *EVE Online*, available on both Mac and Windows. The overall game is a space-based multiplayer that revolves around exploring the virtual universe, while Project Discovery utilises the players to conduct real-life science.

By taking the vast amount of data collected by the Convection, Rotation and Planetary Transits (CoRoT) satellite, players of this game can discover new exoplanets. It's a citizen-science project in disguise, taking advantage of a free online game to sift through large amounts of data - a feature that works cleverly when teasing out vital information in making a discovery. Even though computers are great for collating CoRoT's data, the human mind can spot the subtleties in a star's light curve, unveiling what could be a new and exciting planet orbiting a different star.

We particularly enjoyed the feature where you're giving rewards for your efforts in crunching through telescope data. Project Discovery gets a massive thumbs up from us.

3 Accessories **SkyTech LPRO MAX Canon EOS Clip Filter**

Cost: £169 (approx. $235) **From:** Altair Astro

Having trouble with light pollution? It's every astronomer's nemesis, especially if you live in a crowded city. It's difficult to even see stars, let alone achieving the task of photographing nebulae.

This is where the SkyTech LPRO MAX filter comes in handy, as it is compatible with all APS-C-sized Canon EOS cameras, but not full-frame cameras. This filter also cannot be used with EFS lenses due to the rear element hitting the filter. Once the accessory is attached to the Canon camera, large amounts of unnecessary light pollution can be blocked out – as well as ultraviolet and infrared light – to create sharper images.

While there are other similar SkyTech filters, such as the CLS and the CLS-CCD, the LPRO MAX is more specialised in landscape astrophotography. Whether it's trying to observe the glow of the Milky Way trail without the glow of the city lights, or snapping a star trail throughout the night, this filter does a marvellous job.

4 App **GoSkyWatch Planetarium**

Cost: £3.99 / $3.99 **For:** iOS

The GoSkyWatch Planetarium is exactly what you want from a pocket-sized planetarium. Its augmented reality allows you to spin around in circles as you identify the many objects of the night sky. This includes a wide array of planets, stars, constellations, comets and two catalogues of deep-sky objects: Messier and Caldwell.

The navigation and control of the software is extremely easy, and it even gives you a simple on or off approach to changing the settings. A great setting change is the ability to switch into 'Night Mode', which washes everything in a red light. The red light allows you to keep your night vision, so you won't have to spend another 30 minutes waiting for your eyes to adjust.

With that being said, we feel that the catalogue could have a more in-depth astronomical archive, possibly including more objects from the New General Catalogue. This would provide additional targets for more advanced astronomers, or new challenges for a beginner. In our opinion, GoSkyWatch serves as a more versatile planetarium over free apps we have used - the quality certainly matches the price!

“[Project Discovery] is a citizen-science project in disguise”

Werner Heisenberg

He won the Nobel Prize for his revelations in the field of physics

Heisenberg's uncertainty principle is now common knowledge among physicists

Werner Heisenberg is one of the key innovators when it comes to quantum mechanics, a subsection of science that explains the behaviour of the smallest particles composing the entire universe. His groundbreaking work in a time of raging war changed the world of physics for the better.

Born on 5 December 1901 in Würzburg, Germany, Heisenberg began his journey into physics and mathematics in the early 1920s, where he studied the subjects extensively at universities such as Munich, Göttingen and Copenhagen. At these institutes he worked with some of the world's finest minds, including Niels Bohr and Max Born.

Throughout the 1920s there was an influx of discoveries surrounding the field of quantum mechanics. Slowly, the nature and behaviour of small particles was becoming clearer, and Heisenberg played a big part in that. While working as Professor of theoretical physics at the University of Leipzig, Heisenberg was revolutionising the field. In 1925, Heisenberg had formulated quantum variables in terms of 'matrices' and created matrix mechanics, which in possible layman's terms states particles obey non-commutative rules and can only be explained with unobservable quantities. Shortly after, in 1927, the famous 'Heisenberg uncertainty principle' was formed, stating that a particle's momentum and position cannot be known to a high degree of certainty, and that it's either one or the other.

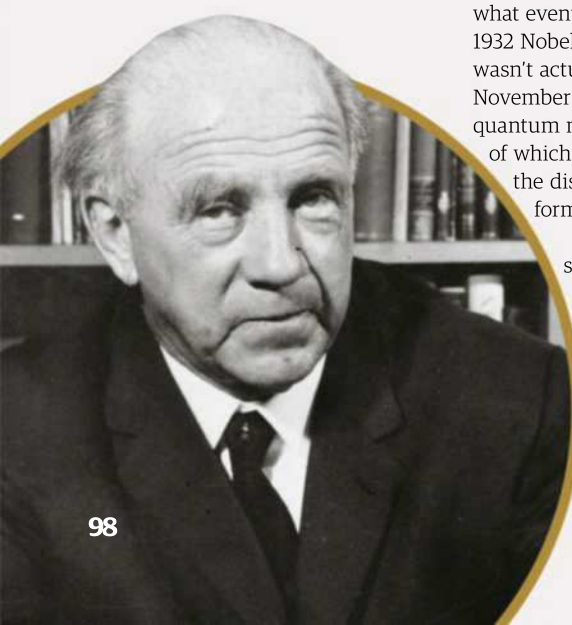
> "The nature of small particles was becoming clearer, and Heisenberg played a big part"

These concepts are still difficult to wrap one's head around now, so for Heisenberg to formulate such equations and explanations is testament to his incredible intelligence and originality. This is what eventually led him to win the 1932 Nobel Prize for Physics, which wasn't actually announced until November 1933, "for the creation of quantum mechanics, the application of which has, inter alia, led to the discovery of the allotropic forms of hydrogen".

Unfortunately, in the same year of his Nobel Prize victory, the Nazi Party was looming towards power in Germany. Their ideas and beliefs led to Heisenberg, among others, becoming the target of much defamation due to the fact his work on theoretical physics opposed the 'Deutsche Physik' (German Physics) movement.

Being the German nationalist he was, Heisenberg continued to serve his country during World War II by working on their nuclear weapon project. The Nazis developing a nuclear weapon is a scary thought, but the Germans believed that if anyone could do it, it would be Heisenberg. Obviously, in hindsight, the Nazis had neither the collective minds nor the resources to pull off a project like this, leaving them in the shadow of the Manhattan Project.

After the war had ended, Heisenberg eventually went back to continuing his fantastic work in quantum mechanics, and cosmic rays in particular. Coupled with this work, Heisenberg took on many chief positions in multiple institutes, as well as 'spreading the good word' of his field in the form of public talks across Europe. Sadly, Heisenberg passed away on the 1 February 1976 due to cancer, closing the curtain on the vital role he played in developing our current understanding of physics.



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